1937

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DI CARLO - 1937

AN EXPERIMENTAL STUDY OF ASSIMILATION BETWEEN ABUTTING CONSONANTS:

AN INVESTIGATION OF THE DEGREE AND THE DIRECTION OF ASSIMILATION UNDER VARYING CONDITIONS OF RATE AND ACCENTUATION

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Thesis submitted for the degree of Master of Science

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Amherst, Massachusetts

May 22, 1937

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INTRODUCTION

Assimilation, a specific process of speech change, is not a new problem. Avery, Dorsey, Sickles (1-p.137) and Grammont (1-p.186) suggest that assimilation accounts for by far the greatest number of changes throughout the evolutionary history of languages. This study is an experimental investigation of the degree of assimilation as it occurs between abutting consonants (consonants which come together at the end and beginning of successive syllables) under varying conditions of rate and accentuation.

REVIEW OF THE PROBLEM

Speech change, both as process and phenomenon, has concerned linguists and phoneticians from early antiquity. Regularity of occurrence of speech changes has lead to the formulation of general laws of phonetic mutation,[1] and almost any classical rhetoric or language treatise alludes to the law or laws of language (9-p.104). The extended operation of phonetic changes in space and in time not only creates new language combinations, but also is an important factor in the generation of new languages[2] (10). Assimilation in Latin spreading

[1] Any modern language or phonetic text contains at least a descriptive account of these laws.

[2] Spengler, Oswald: The Decline of the West. New York; Alfred A. Knopf-1932 Volume 2: "Languages migrate in that they spread by carriage from tribe to tribe"; p. 119. But he recognizes that melody, rhythm, stress cannot pass on to alien successors: p. 117.

over a large area and through hundreds of years has influenced the development of the Romance languages.

A cursory glance at the history of linguistic and phonetic theory reveals that the early Greek scholars were quite aware of assimilation in their own speech. Characteristically they tried to account for the change, but since they lacked experimental apparatus, logical necessity impelled them to explain assimilation theoretically. They seized upon the mind (vous) as the most expedient and efficient solution, although a crude motor theory was not unknown to some of these early phoneticians[1] (3). This concept, that the action of the mind is responsible for assimilation, colored phonetic thought for generations; even today its reverberations are still very strong.

Although phonetic and linguistic speculation and research have produced conflicting theories purporting to explain sound change, all investigators agree that assimilation is a special kind of sound change. Vendryes (17-p.61) suggests that assimilations occur between two sounds when one borrows from another, when one influences another, or when one fuses with another to produce a hybrid or third sound. Sound changes that take place suddenly without any intermediate stage are classified

[1]Aristotle recognized the iambic metre to be "the readiest metre in speaking."

under assimilation and are sometimes referred to as the loss of consonants in heavy groups (8-p.168). These changes are probably due to the simplification of compound and multiple consonants especially prevalent in the speech of young children. Moreover, the reciprocal influence which phonemes (single elements) exert upon each other results in assimilation (4-p.37).

Generally, assimilation takes place between contiguous sounds. The phonemes that are affected are in juxtaposition so that the resulting sound change can be immediately detected and calculated. Assimilation is progressive when the new sound follows the originally intended sound, e. g., colnis becoming collis (4-p.231). If the process is reversed, i. e., interlego becoming intellego, assimilation is regressive (4-p.231). Labhta becoming labtha (4-p.231), godsibb becoming gossip (4-p.231) are offered as examples of assimilation operating in both directions. In all these cases assimilation occurs between adjacent phonemes. Sometimes assimilation occurs when the phonemes are not adjacent. In these cases assimilation is not so apparent. Pequo becoming coquo (17-p.61), and computare changing to count (4-p.231), are examples of this type.

All these descriptions are compatible with each other and consequently lend themselves nicely to the formulation of a general categorical definition. Moreover, they all embrace the

implication that assimilation is a dynamic process. As a process assimilation is progressive since its phenomena are a series of events transpiring in time. The process is illustrated by the word assimilation itself, a derivative of the Latin preposition ad and the verb similare which united to form assimilare meaning to make like. In the process of change the sonant (voice) stop d of ad lost its sonant quality and disappeared as an arresting consonant, but remained in the spelling as a continuant surd (voiceless). From assimiletus, the past participle form of assimilare, comes our own word assimilation in which the t of the participle ending has become sh and the arresting s has changed to the nasal n. The term illustrates the process and defines it as:

1. A specific kind of change occurring between sounds when one:
    a. is influenced by another, e. g., godsibb becoming gossip where the d is influenced by the following s (4-p.231);
    b. influences another, e. g., in Is this your bag? the s of this influences the y of your so that the phrase eventually becomes is thi shore bag?
    c. fuses with another to form a third sound, e. g., would you becoming wuju (18-p.91).

Although scholars have agreed upon definition, their endeavor to explain assimilation has produced a number of different concepts. The one which probably has found the widest usage attributes sound changes to the "anticipatory action of the mind." Vendryes (17-p.62) has stated this theory clearly: "The speaker, preoccupied with the pronunciation of a certain phoneme coming in the middle of a phonetic group, utters the sound earlier than he should, and produces the desired articulation twice in succession. The vocal cords have a memory." Sound alterations result from a lack of coordination ("lack of attention") between concept and vocal organs (17-p.63), "for in the final analysis the change is in the mind of the speaker" (17-p.64). Again, "The position of the speech organs required for the formation of the inducing sound is said to be anticipated completely or in part while the induced sound is being uttered." (17-p.61).

In the first description the anticipatory action of the mind is explicitly credited with causing the change, while in the second, the mind as cause is implicit. Paradoxically enough, both descriptions emphasize the utterance of sound, but this suggestion for a movement theory is not realized. Neither contains a movement analysis or motor theory of speech.

The insistence that the mind performs some function in speech depends upon the metaphysical demand that mind exists a priori and independent of objective experiences (objective

in the sense that experiences, properly behavior, may be physical or physiological tensions). According to the mind theory, the a priori and independent existence of mind in a realm of mental essences is reality, but its instrumentalities include facts of a non-mind order. The interplay between total situation and reaction can never falsify the action of the mind since both situation and reaction owe their existence to the mind. Neither total situation nor reaction can influence the mind, since the mind determines and influences both. The connection between mental factors and speech organs, according to this theory, is neither esoteric nor puzzling, but simply the natural and unequivocal action of the mind. Such relationships, however open they might be to serious question, do not lend themselves to fruitful experimentation. They do not fall within the boundaries of objective verification. Moreover, a consideration of the mind involves an excursion into other related metaphysical problems of Intellect and Will which, while interesting for armchair speculation, ultimately terminate in a mental futilism which can neither facilitate nor expedite our approach and method. In addition to inherent inconsistencies of its own, a logical analysis of the mind theory discloses that it is based on some recondite hypothesis which permits a speaker to pay more attention to the articulation of one or more phonemes to the neglect of others. The "anticipatory action of the mind" seems to have an affinity

with some favored phonemes which prejudice it against others. The reasons for these preferences are not clear, but the theory might undergo further refinement to include the "unconscious". Indeed, Freud's explanation for slips of the tongue could be the starting point for such a theory.

In an experimental investigation of assimilation the mind theory is little less than useless. The great interest in speech lies in its social function: "Prescribed meanings." But these meanings need not be facts of a mental order. They are as objective as the needs which they have come to symbolize, and are inextricably interwoven with every detail in the totality of the experience patterns which conjure them up. Consequently, for the purposes of this study, mental causation as an explanation of assimilation is neither adequate nor satisfactory. The strongest challenge any opposition to mental causes must meet is the hopeful belief that the inability to disprove mental causes establishes their existence. Logically such a position is untenable since the criteria of proof do not rest on the absence of proof. A better approach would be to show that even if mental causes cannot be disproved there remains the possibility of adducing adequate evidence to support explanations that would render recourse to mental causes unnecessary.

An illustration may help to clarify this part of the problem. As a result of business needs a person makes reser-

vations to take the 5 o'clock train. At 4:45 the realization that he must complete a certain task before he can depart begins to disturb him. Each successive minute aggravates his fear of missing the train. That physical tensions are operating is manifested by his behavior. A friend, who can without inconvenience, finish the task enters the total situation. The person turns to his friend and asks him to complete the work for him. His friend may inquire why he does not finish his own work. He may receive any one of the following answers:

1. Can't you see, I'm in a hurry.
2. Can't you see, I'm inu hurry.
3. Can't you see, I'm inu hurry.
4. Can't chu see, I'm inu hurry.
5. Can chu see, I'm inu hurry.
6. Can chu see, I'm inu hurry.
7. Canch see, I'mnu hurry.

This list does not exhaust all the possible replies. The final pattern the speaker uses, however, will probably not be determined by the speaker's mind, but rather by the tensions of the whole situation. Under certain conditions abutting consonants will fuse (t:y to ch), arresting consonants will move towards the releasing position (in a to inu), and finally consonants and even syllables will be eliminated (can't you to canch). To attribute these changes to the speaker's mind

is to ignore the dynamics of speech and total situation.

Another formula which purports to account for assimilation is the "Ease Theory" (8-p.261-263). The law of economy is the crux about which this theory pivots[1] (1-p.137). Jesperson goes so far as to attribute to all humanity a universal "tendency to follow the line of least resistence," (8-p.263). He is among those scholars who reason that sound changes follow the direction of greatest ease. He introduces a movement theory within which the law of economy operates (8-p.263), but eventually he depends heavily upon mental factors to account for data which the law of economy might fail to circumscribe. "Over and above mechanical principles we have here and elsewhere psychological principles, which no one can disregard with impunity" (8-p.273). According to this theory, mental factors and the law of economy together ought to explain away any case of sound change.

It is quite manifest that economy of effort functions prominently in producing assimilation, but economy of effort does <u>not</u> <u>necessarily</u> mean least resistence. Often ballistic movements, especially speech movements which are difficult to

[1]Graff, Grammont, Jesperson, Vendryes, and especially Zipf make a good deal of the law of economy. Avery, Dorsey, and Sickles suggest that: "Many students of linguistics deny the importance of this factor, but every teacher of language knows how natural is the tendency of the vocal muscles to accomplish their end with the least possible expenditure of effort". (p.137)

execute individually, are less difficult to execute when grouped into rhythmic patterns where the movements flow into one another (14-p.302). Resistance may even increase, and, strangely enough, Jesperson recognizes such a possibility (8-p.264), even though he makes little of such a cue. In rhythmic patterns individual movements group themselves into larger unities. The nature of this larger grouping differs from the nature of the unit (smaller) grouping (14-p.258) and (14-p.314). An analysis of the nature of the ballistic movement suggests that the beat stroke phase is less subject to control than the back stroke phase (14-p.263). The conditions making assimilation a fact are those which apply to, and limit, the coordinations of the elaborate musculature involved, and not those of least resistance. The notion, therefore, that behind the law of economy lurks a tendency to avoid difficult sounds, to eliminate superfluous sounds, or to facilitate in general the work of the speech organs (4-p.265) is inadequate.

Furthermore, with respect to speech there is grave doubt that the individual follows the line of least resistence. This assumption implies that individuals by nature gravitate towards the utterance of slovenly speech. If speech were for the individual alone this claim might have some validity. But once more, the paramount significance of speech is its social aspect. Fortunately, individuals are partners in speech transactions. Speech is of value to the group as well as to the

individuals. Consequently, beyond economy of effort, social compulsions (the need to be understood, social, personal approbation and derision) operate with greater efficacy to preclude reversion to extravagant use of slipshod, incoherent speech. The individual will travel a most arduous route to escape the oppression of social disapproval. Moreover, the tendency to economy is difficult to demonstrate, and for this reason of little use to the experimentalist. The idea of movement is good, but incomplete, since these scholars fail to analyze the syllable pulse and the consonantal functions in relation to it.

Grammont's more recent treatment of the problem describes assimilation in terms of movement: "L' assimilation consiste dans l' extension d'un ou de plusieurs mouvements articulatiores au delà de leur domaine orginaire" (5-p.185). He formulates the law of the strongest ("la loi du plus fort") (5-p.185), the only law which assimilation obeys. Assimilation changes must progress in an orderly fashion because they are constrained by the evolutionary laws of the particular phonetic system (5-p.185). Consonants are strong by "position" (5-p.186). In an abutting consonant pair the initial (releasing) consonant is the stronger by "position." The final (arresting) consonant of the pair supports (appuyante) the releasing which is the supported (appuyee) consonant and protects it from the influence of the vowel of the proceeding syllable (5-p.186). The supported consonant is buttressed against change

and may even trespass upon the domain of the supporting consonant to influence it. Thus while the supported consonant preserves its integrity by its ability to resist change, the supporting consonant, because of its weak position, loses its identity (5-p.186). Two influences effect the final (arresting) consonant of an abutting pair. First, since the supporting (arresting) consonant follows the vowel, it acts as a buffer between the vowel and the initial (releasing) consonant; it absorbs the residue sonant phase from the vowel coordination. Second, it is also acted upon by the releasing consonant. Eventually these two influences obliterate its identity. In the phrase bec de livre the c is voiced because it supports the sonant d which in turn invades the region of the c articulation (5-p.186). Likewise the b of une robe courte is influenced by the unvoiced supported c (5-p.186). The law of the strongest functions with immutable efficacy; "A cette loi il n'y a d' exceptions et il ne saurait avoir" (5-p.186). Grammont follows this description of his thesis with an explanation. He maintains that each articulatory movement consists of three phases: "catastase--tenue-- metastase". These phases correspond exactly to Rousselot's analysis of the vowel and consonant movements: "tension--tenue--detente" (5-p.15-16). The "catastase" is the taking of position which closes the vocal canal. In the articulation of p the lips are brought together

to close the vocal canal. The "tenue" is the holding position during which the articulatory process maintains the closure, the time during which the lips remain together for the p (occlusion). The "metastase" represents the quitting position which opens the vocal canal. This phase is the stroke away, or the opening of the p articulation. Grammont labels the weak (arresting) consonant "implosive" and the strong (releasing), "explosive". The crucial point for assimilation lies in the region between the "implosive" and "explosive" juncture. The sound change occurs between the "metastase" of the "implosive" and the "catastase" of the "explosive". Abna, becoming Anna, is among the many examples he offers as an illustration of this principle (5-p.191). At this critical ("weak") point (between the metastase of the b and the "catastase" of the n) the speech organs are relaxing; they are in a transition stage and therefore in an easy position to become dislocated and unbalanced (5-p.191). The weak "metastase" of the "implosive" (supporting) b is quickly cut off by the "catastase" of the "explosive" (supported) n. Nasality attacks the b at this unstable juncture and prepares it for change (5-p.191).

So far Grammont's consideration of the problem has been based on an analysis of the articulatory organs. But the vexing question as to why one articulatory movement superimposes itself on another requires final explanation. To the law of the strongest he adds concepts of cerebral and muscular

attention (5-p.191). In articulations involving mn, bn, or phm, the nasal, being stronger by "position", assaults the weaker consonants preceding it (5-p.191). This invasion attracts cerebral attention to the specific character of nasality. Cerebral attention effects the dropping of the soft palate as soon as the occlusion for the arresting consonant gets under way (5-p.191). By the end of the "tenue" phase of the weak ("implosive") consonant the velum is completely closed so that the "catastase" of the nasal, strong ("explosive") consonant cuts off the "metastase" of the weak ("implosive") consonant. The mind now attends the articulatory process. To muscular attention is delegated the task of preparing and executing the articulatory movements. Finally cerebral attention devotes itself to words (5-p.191).

In spite of the emphasis of the articulatory movements Grammont's theory does not contain an adequate analysis of the consonantal function in relation to the syllable pulse. Stetson (11-p.17-18) offers a convincing criticism of the "catastase--tenue--metastase" description and demonstrates that the "implosive--explosive" is not fundamental to the syllable pulse (11-p.15). The notion, therefore, that the crucial point for assimilation lies in the region between the "implosive--explosive" juncture is not adequate. Furthermore, under certain conditions the law of the strongest fails to function. Grammont recognizes such an anomaly in the c of

un bec gigantesque (5-p.194), for although the c is supporting, it not only resists change but also influences the supported consonant g. But he immediately minimizes this aberration: "uand la voyelle qui precede la c'est accentuée comme dans un bec gigantesque il arrive que la premier partie de la tenue du c reste sourde; c'est que le c'tient alors, comme on sait, de l'accent que le précède, un renforcement qui lui permet de résister au debut; c'est que s' il doit a l'accent une tension plus forte" (5-p.194). It now becomes unmistakeably evident that at least one other factor intervenes. Perhaps to the "law of the strongest" may be wedded the law of the weaker so that changes not conforming to the mandates of one law may readily follow those of the other.

Zipf (18) has approached the problem in a somewhat different manner. He defines assimilation as: "change in the position or manner of articulation of near or contiguous phonemes" (18-p.90). "Sometimes contiguous phonemes are assimilated to one another to form a third": would you becomes wuju, courtyard, courchard (18-p.91). The germ for a movement theory is conspicuous in the definitions but Zipf never carries it to logical fruition. Furthermore, "every assimilation points to a weakening or instability of the assimilated sound, and this weakening is caused primarily by the excessive frequency of the assimilated sound" (17-p.109). He sees a causal relationship between the relative magnitude

of the complexity of a phoneme and its relative frequency (18-p.81). This relationship can be established from examples of change in relative magnitude of complexity connected with a change in relative frequency of occurrence (18-p.81). But he also recognizes "extensive changes which may seriously affect both the magnitude of complexity of phonemes and their relative frequency of occurrence" (18-p.87). He saves his theory by recourse to "Equilbruim", the force which preserves and restores the phonetic system (18-p.87). There is too much against the concept of causal connection between relative frequency and relative complexity as an explanatory principle for assimilation. Zipf's own examples wuju and courchard do not demonstrate the causal connection since speed of utterance and accent pattern are ignored. Zipf also fails to recognize the relationship of the consonantal function to the fundamental syllable pulse.

In his discussion of speech movements and their coordinations Stetson (11) discusses several aspects of the problem concerning the reciprocal influence of sounds on each other. "There is a 'law of assimilation' whereby movements tend to become alike" (11-p.203), but more important: "it is a general law of language that all phonetic coordinations shape themselves by and for the maximum speed of utterance" (11-p.203). Speed, then, conditions sound changes because in order for the phonetic coordinations to remain in phase

and function in the stream of speech, certain modifications must occur as these coordinations approach maximum repetition time (physiological limit). Consequently, reasoning that hopes to account for speech changes must refer to the speech movements involved.

Speed, however, is not the only factor in speech. In spite of the influence of speed in shaping sound changes, several other factors operate concomitantly to preserve or restore speech coordinations. Meaning, if necessary to comprehensibility, will prescribe a reduction of speed and in this way will keep the movements distinct. Accent guides in grouping the movements. Inevitably, the details of pronunciation will depend upon the rhythm because rhythm at high speed will be responsible for full or slurred pronunciation (11-p.206). "In the end rhythm guides the phonetic changes which every language is undergoing" (11-p.206).

Stetson has made an exhaustive study of the problem concerning the influence of speed of utterance on abutting consonants. At rates of syllable utterance exceeding 3.5 per second consonants do not remain separate (11-p.91). Consonants may abut at a rate of two syllables per second and continue up to four syllables per second (11-p.91). Abutting consonants cannot persist beyond the rate of four syllables per second (11-p.91), because the eight consonant movements which occur in the coordinations of the four syl-

lables represent, or almost approach, the physiological limit of the repetition time of the articulatory organs. The arresting consonant will be modified: top top... becomes pto.... and finally to..... (11-p.104); sam sam.... becomes msa and sa (11-p.105); mas mas..... changes to sma... then ma... (11-p.106); bos bos..... changes to sbo... ; sap sap..... to psa... ; pas pas... to spa..... (11-p.107). Eventually all arresting consonants either drop out or become part of the releasing consonant of the next syllable. They finally coincide with the releasing consonants, which indicates that they have lost their function as arresting consonants, and drop out of the syllable coordination. This consonental behavior suggests a possible approach to the problem of assimilation. The arresting consonant may drop out at a rate as low as 2.5 per second (11-p.91). Indeed whole syllables may drop out at rates of 2.9 syllables per second (15-p.33).

This report is an extension of the work suggested by Stetson in "Motor Phonetics" (11). In his study he has broadly hinted at the changes which might occur before the arresting consonants lose their function in syllables. This study is a detailed account of these changes.

NORMAL SPEECH COORDINATIONS

Speech consists of a series of rapid highly skilled movements of the breathing and articulatory muscles[1]. The stream of normal speech tends towards high speed during which the units cluster about minimum limits. Speech movements like all highly skilled movements have thresholds of maximum rate (physiological limits). Assimilation or other speech changes indicate a change in the coordinations of speech movements. Graphic records of these movements clearly show the changes in progress.

The ballistic movements of the chest muscles produce the syllable pulse, the fundamental unit of speech, while the larger abdominal muscles support the action of the chest musculature in producing a series of syllables and fuse these syllables into a single breath-group, or phrase, on the expiratory phase of respiration. The syllables are grouped into rhythmic units or feet which in turn are grouped into a larger unit (the phrase) by the action of the abdominal muscles.

The action of the abdominal muscles presents a controlled type of movement which provides a support for the action of the smaller chest muscles. As the positive muscles contract,

[1]For a brief, clear discussion of speech movements see: "A Comparative Study of Speech Movements of Deaf and Normal Subjects: C. V. Hudgins: Journal of Genetic Psychol. 1934, 44, 3-48. For a detailed and comprehensive study see: Motor Phonetics R. H. Stetson, Arch.neerl. d. phonet. exper.,1928,3, 1-216.

the chest cavity is compressed, and the air pressure increases. A puff of air is forces upward through the trachea on the beat stroke. The negative muscles arrest the syllable by stopping the puff of air.

The consonant movement also consists of a beat and back stroke. It, too, falls in the category of ballistic movements. Consonants have no independent existence in speech but coordinate in the syllable movement either to release or, to arrest it.

The beat and back strokes of the releasing consonant occur on the beat stroke of the syllable pulse. Both movements start together. The beat and back strokes of the arresting consonant fall on the back stroke phase of the syllable pulse. At sufficiently slow rates of utterance it is possible for both the releasing and the arresting consonants to function in the syllable coordination. But speech tends towards high speed, and as it approaches high speed it also approaches the maximum repetition time (physiological limit) with which the consonants may be spoken. As the rate of syllable utterance increases from two to four syllables per second, the consonant movements increase from four to eight. Stetson has shown that under certain conditions, (repetition rate of less than five syllables per second) double consonants (a special form of abutting consonants) may fall to a minimum of .15 seconds. Such lengths, he suggests, are rare (11-p.80). A more probable minimum length for double conso-

nants falls between .20-.25 seconds (11-p. 80). If the minimum length of the abutting consonants is .15 seconds, then at four syllables per second the arresting and releasing consonants of the abutting pair may function provided the vowel length does not exceed .10 seconds. Beyond this rate, however, abutting consonants cannot occur, since time will not permit them to function in their proper syllables. Stetson has further demonstrated that at high speed arresting consonants: (a) abut with releasing consonants of the following syllables (11-p.69); (b) shift to the releasing position to combine with releasing consonants to form compounds (11-p.107); (c) become vocalized (11-p.107); and (d) finally lose their function as arresting consonants and drop out of the syllable coordination (11-p.191).

There are two different and essential movements in speech: (1) the chain of syllables which is the fundamental series of movements; and (2) the dependent series of consonant movements (13-p.246). In the first case the independent chain of syllable movements carries the rhythm and accent of speech. In the second case the consonant movements are concomitant with, and exist only insofar as they function in the syllable movements. The syllable movements are the fundamental movements and the consonant movements must accommodate themselves to these fundamental syllable pulses. Changes of rhythm, stress, and speed of utterance will force a change in this

interrelationship: "Changes of rate, stress, and rhythm may force the consonants to shift position and function from one syllable to another, to combine into compound consonants, to decompose into single consonants and in some cases to drop out" (13-p.249). The crux of the problem of consonant assimilation lies in this interaction between the independent syllable movements and the consonant movements.

It is a matter of common sense that at high speed the syllables are crowded closer and closer together. If more syllables are spoken in a given time, the interval between them as well their lengths decrease. The arresting, rather than the releasing, consonants must drop out because time will not permit them to function in their proper syllable coordination. The arresting consonant, rather than the releasing consonant, adds length to the syllable, since it falls on the back stroke of the syllable movement. At high rates, above 4 syllables per second, syllables become very regular and self-arresting.

Since the stream of speech progresses at high speed the separate movements of the speech organs are organized into groups which fuse into larger unities. Accent figures prominently in the organization of the unit groups. Accent involves a stress--a greater contraction of the positive muscle groups of both the breathing and the articulatory apparatus. A greater contraction of the positive muscle

groups necessarily entails a longer relaxation phase. Accented syllables will be of a longer duration than unaccented syllables. Longer relaxation phase of the syllable movement will permit time for the arresting consonant to function. The accent, therefore, whatever its prime cause, has a point of emphasis (culmination) which assures the arresting consonant a place in the coordination. Both the grouping of the syllables into unit groups, and the degrees of accentuation and subordination of the individual syllables, determine the speech rhythm. Speech rhythm is simply a special form of the ordinary coordination of movement experience. The simplest form of rhythm experience seems to be a perception of a peculiar type of likeness and repetition in a movement series (14-p.256). These persistent recurring patterns of movement are produced by slight movements of the articulatory muscles in conjunction with the expiratory muscles which mark the main accents. Consequently the basis of rhythm is the movement cycle which consists of a rapid beat stroke and a relatively slower relaxation phase (back stroke) (14-p.157). There is much to recommend the idea that rhythm is a group of movement patterns embracing variation, subordination, accentuation, and synthesis (2-p.256).

Larger units, as well as accented syllables, involve stress and increased force of muscular movement. Each movement has its dynamic culmination point, and larger movements

are no exceptions. Therefore, both the play of word accent and the rhythmic grouping of phrases are necessary for good speech coordinations. It becomes evident that word accent will be instrumental in not only determining the functions of the consonants as arresting and releasing, but also in what syllables these consonants will function. This consonantal behavior offers a cue to the present experimental study of assimilation.

THE PROBLEM

Unquestionably, assimilation presents a highly complex problem. Assimilation may occur between:

1. Vowel and vowel
2. Vowel and consonant
3. Consonant and vowel

Realization of the magnitude of this complexity prescribes the limits of this investigation to only one aspect of the problem: assimilation that occurs between abutting consonants. The problem resolves itself into a study of the process of assimilation by inducing assimilation in the speech of a group of normal subjects. Graphic records of this process can be obtained. Such records permit quantitative measurements. Thus, it is possible to study the

process of assimilation in action by the methods of experimental phonetics. The problem, therefore, is to induce assimilation in special cases (abutting consonants) and to determine the factors involved and the conditions under which assimilation occurs. This involves the determination of the following:

1. Just how one consonant affects another when the two are juxtaposed at the end and at the beginning of adjacent syllables;
2. Under what conditions one consonant is assimilated by another;
3. Under what conditions the two consonants combine to form a third;
4. What factors, other than mere juxtaposition, are responsible for the mutations that occur.

APPARATUS[1]

A variable-speed, motor-driven kymograph (holding and rotating a drum) carrying a smoked record 26 by 6 inches was employed throughout the experiment. Speech movements

[1]For a description of the apparatus see: "A Comparative Study of the Speech Movements of Deaf and Normal Subjects"; C. V. Hudgins: Journal of Gen. Psych. 1934, 44, 10-13.

and the air pressures developed by these movements were transmitted to the smoked sheets by means of pneumodeiks. These pneumodeiks consisted of phosphor-bronze bellows-diaphrams, jewelled bearings, and pulley with attached stylus (bamboo). A string attached to the diaphrams rotates the pulley and this moves the stylus in an arc. The pneumodeik is extremely sensitive to slight pressure changes. It may record voice vibrations up to 500 dv. per second. In addition, the metal diaphram is permanent and permits quantitative comparisons of air pressure tracings made over a long period of time. These two factors make the pneumodeik a desirable and very useful instrument for the type of research to which the problem of this report belongs.

Changes of the air pressure in the mouth behind the consonant occlusion were obtained by a metal tube with a lumen 4 mm. in diameter. In order to allow the articulatory organs maximum freedom of movement the metal tube was shaped and curved to fit into the corner of the mouth and to pass back to the rear of the mouth paralleling the teeth. A sharp bend near the end of the tube permitted it to enter the oral cavity proper around the last molar and to rest in a position in the region of the oral pharynx. Besides providing minimum interference to the speech organs the ends of the tube lay in a position posterior to the point of consonant occlusion. Thus it was possible to tap the air pressure for all consonants,

including the k and g. Air pressure from the nose was recorded by nasal olives. The air pressure just outside the mouth, including vocalizations for the vowels, was recorded by means of an aluminum "embouchure" constructed from a medium size aluminum funnel cut and shaped to fit the contour of the mouth. A small hole ventilated the "embouchure". This arrangement allowed the subject to breathe, but still recorded the air pressure changes in speech. Rubber tubes connected the metal tube, nasal olives, and the "embouchure" individually to pneumodeiks or to a voice tambour. A magnetic fork recorded time in intervals of .01 sec. A telechron clock motor operating a marker recorded time in intervals of .04 or .1 sec.

PROCEDURE

Kymograms were taken from twelve English-speaking adults (eight males, four females), namely one college professor, five teachers of the deaf, and six graduate students. All but two subjects were naive as to the nature of the experiment. The tracings of the air pressures from inside the mouth revealed the rise of air pressure in the mouth and vocalizations during the consonant occlusion. The tracings of the air pressures outside the mouth showed a straight line for consonant closures, and a rapid rise and vocalizations for

the vowels. The nasal clives indicated the air pressures and vocalizations from the nose. Tracings of the air pressures from inside, outside the mouth, and from the nose were made simultaneously whenever necessary.

Before the actual recording, each subject was instructed in the use of the apparatus. A period of instruction was followed by a period of practice until each subject had learned to speak naturally with the apparatus. This orientation allowed the subject to become familiar with the apparatus, relax and become adjusted to speaking with the apparatus. Prolonged drill with proper speech material and accent insured normal, natural speech. This reduced the apparatus problem to its simplest terms.

Each subject repeated sense and nonsense syllables and phrases containing abutting consonants at different rates of speed and with different accent patterns. Each subject was instructed to begin slowly, and gradually increase his rate of utterance in order to insure an even increase in speed. The nature of the problem determined the choice of syllables, accent patterns, and rate of utterances. The meaningful syllables and phrases were those which the subjects might easily use in every day conversation. Complete control of the investigation was assured by the employment of the same material with each subject. The constant elements consisted of the speech material, while accent and rate of syllable

utterance made up the variable elements.

The speech of the twelve subjects presented varying degrees of individual differences. These differences were manifested chiefly by the individual management of the air pressure above and below the glottis during the speech process. The tracings from the four female subjects showed a marked decrease in amplitude of voice vibration and air pressure when compared with the tracings obtained from male subjects. The air pressure curves of the male subjects presented a minimum range of individual differences. These individual differences did not introduce any additional factors to complicate the problem. Analysis and interpretation of the air pressure tracings for all subjects clearly exhibited a marked similarity after the differences were calculated.

Exact measurement of the tracings was possible. The tracings from just outside the mouth (vowels) defined the two-member syllables open at both ends (akga). When syllables were released and arrested by consonants (bagpipe) the tracings of the air pressure inside the mouth marked the boundaries of the two syllables. The beginning of the air pressure rise for the releasing consonants of the first syllables marked the beginning of the syllable groups. The point of maximum air pressure of the arresting consonants marked the end of the arresting consonants and the end of the syllable groups.

An arbitrary method was used in determining the threshold rate of change for the speed series in which the abutting consonants fused to form a third sound. This threshold rate was obtained by finding the average of:

(1) the rate of the syllable immediately preceding the change;

(2) the rate of the syllable at the point of change.

The syllable immediately preceding this threshold rate, which in all cases showed the originally prescribed form of abutting consonants, was measured and the rate determined. This rate defines the upper limit at which the two consonants retain their identity. The syllable immediately following the threshold of change, which in all cases revealed that complete change had occurred, defined the limit at which abutting consonants were not possible. In a very few cases the change required four syllables before it became complete and permanent. In these cases the four syllables were measured and calculated to indicate the threshold of change. The syllables immediately preceding and following this indicated the threshold before and after change.

The degree of assimilation was determined by the relative length of the surd and of the sonant phases of the abutting pairs. In all of the speech materials used, the abutting pairs consisted of either an arresting surd and a releasing

sonant, or an arresting sonant and a releasing surd. The relative lengths of the surd and sonant phases, therefore, determined the extent, or the degree, in which one member of the abutting pairs influenced, or was influenced by, the other. The average lengths of the sonant phase, and the total length of the abutting pairs were plotted against the rate of syllable utterance. Curves were plotted for each of the different accentual patterns used. This graphic representation makes it possible to determine:

(1) The rate at which complete assimilation occurred;

(2) The degree of assimilation which occurs at varying rates;

(3) Under what specific conditions (degree of accentuation, rate of syllable utterance, relative position) phonemes: (a) were assimilated; (b) resisted assimilation; or (c) fused to form a new phoneme.

RESULTS

Records from different subjects will be presented and discussed in order to show the influence of consonant position, increasing rate, and accent on abutting consonants.

A statistical presentation and discussion of the quantitative data obtained from the large group of records studied will accompany the discussion of the records. The curves plotted from the statistical data will reveal the direction and the degree of assimilation that occurs at varying rates, and the rate at which total assimilation occurs.

The relative duration of the sonant phase to the total length of the abutting pair was chosen as criteria of assimilation. When the rate is varied, or when the accented syllable is preceded or followed by an unaccented syllable, the abutting consonant between these syllables undergoes definite changes. These changes are indicated by the changing length of the two consonants, and by the relative length of the sonant, or surd phase in them. Data will be presented to show that under certain conditions of rate and of accentuation, abutting pairs, either sonant-surds, or surd-sonants, undergo definite changes from their originally prescribed form. The magnitude of these changes will indicate the degree of assimilation. The type of change will indicate the direction of the assimilation process.

1. The Speed Series

Surd-Sonant Series

Records of syllables containing arresting surds and releasing sonants as abutting consonants repeated with in-

creasing rate, show a marked change in the relationship between the total length and the sonant phase of the abutting consonants. The consonant pairs measured for this series show that as the rate of syllable utterance is increased the abutting consonant length decreases quite rapidly, so that by the time the rate of syllable utterance has reached 4 per sec. the consonant length is less than .15 sec. This length is too short for an abutting pair (11 p. 80). When the arresting member of the abutting pair is a surd and the releasing member is a sonant, the sonant phase decreases in absolute length as the rate is increased, but it increases in relative length since the length of the consonant pair is also decreasing. Figure 1, Curve I, and Table 1 show this relationship. At a syllable rate of 2 per sec. the average abutting consonant length is .24 sec. The average sonant phase of the abutting pair at this same rate is .18 sec. At a syllable rate of 3 per sec. the average length of the abutting pair is .20 sec. while the average sonant phase occupies four-fifths of the abutting consonant length, or .16 sec. At syllable rates of 4, 5, and 6 per sec. the abutting consonant lengths are .14, .11 and .10 sec. while their corresponding sonant phases are .13, .11 and .10 sec. As the syllable rate increases both the sonant length and abutting consonant length decrease, but the sonant phase decreases proportionally

much less than the abutting consonant length so that at a rate of 4 syllables per sec. the difference between the sonant phase and consonant length is not a real one. The critical ratio at this rate is 1, which indicates that the sonant phase and abutting consonant are beginning to coincide. From this point on, the two curves for the sonant phase and consonant length draw closer together to meet at a syllable rate of 5 per sec. where total assimilation occurs.

The abutting consonants of this series become almost completely sonant before the arresting consonant drops out. At a rate of 3.4 syllables per sec. the sonant phase occupies 83 per cent. of the abutting consonant length. At this rate the abutting consonant length is .15 sec., the minimum for an abutting pair. At rates beyond 3.4 syllables per sec. the originally prescribed abutting pairs become compound or single consonants which are sonant throughout.

In Figure 2, V the assimilation process appears in its very early stages. The consonants of syllables 1, 2, and 3 have not begun to abut. The inter-syllable space of these syllables, indicated by the return of the air pressure to zero shows the arresting p and releasing s functioning as single consonants in their proper syllables. The syllable rate for syllables 1 and 2 is relatively slow,

ca. 1.6 per sec. Syllable 3 has a rate ca. 3 per sec. This rate is not high enough to cause modification of the prescribed abutting pair to any appreciable degree. Nevertheless the sonant phase of the abutting consonants increases as soon as the consonants p:g begin to abut in syllables 3, 4, and 5. A continuation of the vocalization from the vowel invades the arresting p on one side and the voice from g seems to move backward into the tracing of the p from the other side. Both of these factors reduce and finally eliminate the surd phase of the p. The consonants of syllable 5 show this invasion clearly.

The sonant-surd series

In this series the consonant positions are reversed, but the same general trend of the consonant interaction appears. There is this difference: the degree of assimilation is greater in the early stages (slower rates) and complete assimilation occurs earlier (3-4 syllables per sec.). Figure 1, Curve II, and Table 2 shows this relationship. Assimilation progresses very rapidly as the syllable rate increases to 3 syllables per sec. At this rate the sonant phase occupies 94 per cent. of the entire abutting consonant duration. At a rate of 4 syllables per sec. the sonant phase and the consonant length coincide. At a syllable rate higher than 4 per sec. abutting consonants disappear, but complete assimilation has occurred before the

arresting consonant shifted position to combine with the releasing consonant of the next syllable.

Figure 2, IV, syllables 1 to 6, illustrates the process of assimilation in its progressive stages for this speed series. The arresting consonant preceding syllable 1 and the releasing consonants of syllable 1 have not begun to abut. The consonants g:p between syllables 1 and 2, 2 and 3, are in the early abutting stage. The consonants between syllables 3 and 4 not only abut, but voice from the g almost occupies the entire abutting consonant duration. The sonant phase occupies the entire length of the abutting consonants between syllables 4 and 5. The originally prescribed g:p has become a sonant compound consonant between syllables 5 and 6 at a rate of 3.1 per sec.

The surd-nasal series

The consonant changes occurring in this series follow a somewhat different pattern than those of the surd-sonant series just discussed. Syllables and phrases containing arresting surd and nasal releasing consonants were repeated at increasing rates. Figure 3, II shows the syllables mas, mas... repeated at increasing rates. The syllables from number 8 on have a rate of 3.5 to 4 per sec. The arresting s at this rate has dropped out of the syllable coordina-

tion and has combined to form the compound sm with the releasing m of the next syllable. Assimilation for this group occurs throughout. The s, even before it has shifted its position, however, shows the influence of the abutting m in that the velum opens during the s occlusion, causing the buccal pressure to be dissipated through the open nasal cavity. (See tracing A and B, Figure 3, II.) At this stage the m loses a good deal of its sonant phase. The cause of the loss of voice by the m is probably due to the action of the vocal cords. During the occlusion of the surd arresting consonant air is flowing through the open glottis. As the rate increases, the vocal cords do not have sufficient time to adjust themselves to the voicing position for the m (7, pp. 20-22, and 12, pp. 8-10). At rates sufficiently high the s occlusion overlaps completely the occlusion of the m which regains its sonant phase. (See syllable 14.)

The nasal-surd series

The consonant modifications in this series follow the same general pattern as those discussed in the sonant-surd series. Figure 3, I shows the syllables sam, sam .... repeated with increasing rate. Assimilation for this series is quite rapid and complete at a rate between 4 and 5 syllables per sec. The arresting nasal consonant combines with

the releasing surd of the following syllable to form a compound at a rate of 3 to 4 syllables per sec. But even before this occurs the nasal phase increases relatively with an increase in syllable rate. Syllable 6 shows that the originally prescribed m:s has become a releasing compound mz and the syllable becomes mza. From syllable 11 on, the nasal phase for the m occupies the entire consonant length. (See tracing N and AO, Figure 3, I.)

Hudgins and Stetson[1] have found that the movements of the velum, which is involved in the production of the nasal consonants, are naturally slower than the movements of the lips, tongue, and jaw. Abutting consonants containing a nasal consonant generally do not behave differently than the abutting consonants of the other groups already discussed. But since the movement of the velum is slower than the movements of the lips and tip of the tongue, the change which occurs in abutting pairs containing a nasal consonant would occur at rates slower than that of the other groups. As the syllable rate increases and the abutting consonant decreases in length the velum movement will occupy more and more of the consonant duration and finally overlap the releasing consonant completely.

For the speed series just discussed, pure rate alone

[1] Arch. d. neerl. Phonet. Exper. 12, 1937 (In press)

is the all important factor. There is a tendency for both members of the abutting consonants to become completely voiced. Assimilation occurs rapidly and is complete between a syllable rate of 3 to 4 per sec. The process is a little more rapid for the sonant-surd group.

2. The Spondee Accent Pattern

Surd-Sonant Groups

There is a tendency in this group for both members of the abutting consonants to preserve their identity, and to remain intact as long as the prescribed accent is maintained. Within this limit the accent holds the surd and sonant phases of the abutting consonants in an almost equal proportion, and no assimilation occurs. Figure 1, Curve III shows the relation of the abutting consonant and sonant phase. At syllable rates of 2, 3, and 4 per sec. the average abutting consonant lengths are .30, .26, and .21 sec. while the corresponding sonant phases are .13, .12, and .10 sec. At these rates the ratios between the total consonant lengths and the sonant phases are 2.3, 2.2, and 2.1 respectively. These values are significant because they indicate the constancy of the influence of the accent in preserving the identity of the surd and sonant of the abutting pair up to a syllable rate of 4 per sec. This rate is well within the range of normal speech rates. Hudgins (6-p.35) has found that the

average rate of utterance of 25 normal subjects speaking a 9 syllable phrase (including accent) was 3.8 per sec.

Figure 1, Curve III shows that at a rate of 4 syllables per sec. the abutting consonant length is decreasing rather sharply, while the decrease in length of the sonant phase is relatively small. These two curves would probably coincide at a point near 5 syllables per sec.—which suggests that the accent patterns beyond this rate are modified. That modification of the accent must occur is logical since the rate at which syllables with a double accent can be spoken is limited. This limit is reached at about the same rate as that in which arresting consonants lose their function in the proper syllables. The loss of the arresting consonant, which must drop out as a result of increasing rate, shortens the first syllable of the unit group. With this change in coordination the accent pattern also breaks down, and the spondee becomes an iambic. But at rates which tolerate the double accent pattern the abutting consonants retain their integrity. Thus accent is an important factor in sound change.

Figure 4, I shows the group ape-bay spoken with a spondee accent with increasing rate. Record IV of this figure shows the phrase Will that do? spoken with a spondee accent for the syllables that do at a rate relatively slower than the rate of the groups in record I. Groups 1 and 2, in

Figure 4, III, are spoken at a rate ca. 2.4 and 2.7 per second. The air pressure inside the mouth shows that both the t and d are intact. The t and d of group 2 are in the early abutting stage. The consonants p and b of group 1, in Record I, do not show the abutting form. The surd and sonant phases for the p:b are prominent up through group 5. Beginning with group 6 which attains a rate ca. 4 per sec., the consonants are sonant throughout. The length for the abutting consonants of group 6 is .15, the minimum for an abutting pair. The tracing shows that the buccal pressure is higher for the b than for the p which indicates that the accent is probably breaking down. The accent has broken down in group 7 (not included in the cut). The consonant length was reduced to .13 sec. and the form of the curve showed that the originally prescribed p:b had become a compound or a single consonant. Accent, therefore, influences the trend and magnitude of assimilation that occurs so long as the rate does not exceed the limit of toleration of the double accent. This limit is identical with that at which the arresting consonant loses its function.

Sonant-Surd groups

The abutting consonants of these sonant-surd unit groups spoken with a spondee accent follow general patterns relatively analogous to those of the abutting consonants of the surd-sonant groups spoken with the same accent. (Compare

Fig. 1, Curves III and IV.) The surd phase of the surd-sonant group is of a little longer duration than the sonant phase, while for the sonant-surd groups the sonant phase is of a little longer duration than the surd phase. The position of the surd or sonant as an arresting consonant probably accounts for this slight difference. The spondee accent permits both the arresting and releasing consonant to function in the proper syllables. The relations between the consonant lengths and the surd or sonant phases of the abutting consonants show that little assimilation occurs. At a syllable rate up to 4 per sec. the abutting consonants retain their identity. At a syllable rate higher than 4 per sec. the spondee accent breaks down.

Surd-Nasal Groups

The general relationship between abutting consonants of spondee feet containing surd-arresting and nasal-releasing consonants parallels the same patterns that prevail for the surd-sonant spondee groups. At a rate up to 3 to 4 syllables per sec. the spondee accent holds both consonants firm (not shown in cuts). The average surd phase of the abutting consonant length is slightly longer than that of the average nasal phase. The position of the surd as an arresting consonant which is generally slightly longer than the releasing consonant may account for this larger surd phase. As long as the spondee accent persists, however, both the surd and nasal phases of the abutting consonants are prominent.

As the rate increases beyond 4 syllables per sec. the accent breaks down as it does in the other groups and for the same reasons. The surd and the nasal consonant combine to form a compound consonant which has a relatively large surd phase because, as already discussed in the surd-nasal series above, the vocal cords have not sufficient time to adjust themselves to the voicing position for the m.

Nasal-Surd groups.

The abutting consonants of this unit group (not shown in cuts) spoken with a spondee accent manifest little assimilation so long as the spondee accent pattern persists. The nasal and surd phases do not lose their identity. The nasal and the surd phases are practically equal, indicating that the spondee accent functions for this group with the same regularity and effectiveness as it does in the sonant-surd groups. As the syllable rate increases to a rate higher than 4 per sec. the arresting m moves to combine with the releasing p to form a compound mp. Eventually the velum movement for the nasal consonant overlaps completely the movement of the surd releasing consonant, but the process is the reverse of that just noted in the spondee surd-nasal group. For the nasal-surd groups the voice from the nose occupies the entire consonant length. The vocal cords take the position for voicing the arresting m and do not

have sufficient time to open, during the short occlusion of the releasing p.

Up to a rate of 4 syllables per sec. little, if any, assimilation occurs for the groups spoken with a spondee accent. The arresting consonant phase is generally a little longer than the releasing consonant phase but generally both consonants resist change within this rate limit.

3. The Trochee Accent Pattern

Surd-Sonant Groups

When the trochee accent is prescribed, the arresting consonant of the accented syllable appears to influence the releasing consonant of the unaccented syllable of the unit group, and assimilation is rapid - (within the same limits discussed for the other groups). Figure 5, Curve III shows the trend of the assimilation process, and the magnitude of assimilation. At the rates of 2, 3, 4, and 5 syllables per sec. the total lengths of the abutting consonants are .34, .26, and .15 sec., while the corresponding sonant phases are .11, .09, .07, and .04 sec. At syllable rates of 2, 3, 4, and 5 per sec., the surd phases are 2.1, 1.9, 2, and 2.8 times as large as the corresponding sonant phases. At a rate of 5 syllables per sec. the total consonant length is decreasing very rapidly. The sonant phase begins to increase beyond this rate. The consonant length and the sonant phase probably coincide at a syllable rate of 6 per

sec. At rates higher than 6 per sec. the accent pattern probably breaks down. The arresting consonant combines with the releasing consonant to form a compound or single consonant. The syllables become even, since they consist of single compound releasing consonants and vowels. But up to a rate of 5 per sec. the surd phase is prominent and appears to increase at the expense of the sonant phase. At a rate higher than 5 syllables per sec., in some cases earlier, voice occupies the entire consonant length.

Figure 4, V, shows the relatively large surd phases of the abutting consonants for the three groups. Group 1 has a relatively short sonant phase, .07 sec. for the abutting t:d. Group 2 has a still shorter sonant phase (.06 sec.). Excepting for the brief vocalization from the vowel, present in the arresting t of group 3, the abutting consonants t:d are completely surd. The syllables that do for group 3 have a slower rate (ca. 2 per sec.) than that of group 2 (ca. 2.2 per sec.). Record II of Figure 4 shows the surd-sonant trochee that day spoken at higher rates. In group 2 the surd phase occupies the entire duration of the abutting t:d. The syllable rate for consonants of group 7 and 8 have become compound or single consonants. The syllable rate for group 7 is ca. 5 per sec., nevertheless the surd phase occupies a good portion of the entire consonant duration.

Sonant-Surd Groups

Assimilation is very rapid for the sonant-surd abutting pairs in the trochee groups, but the process is just the reverse of that discussed above for the surd-sonant group. Figure 5, Curve IV, shows the relationship between the sonant phase and the total abutting consonant length. At a rate of 2 syllables per sec. the sonant phase occupies 83 per cent. of the abutting consonant duration. At 3 syllables per sec. the sonant phase is 92 per cent. of the consonant length. At 4 syllables per sec. the critical ratio between the sonant phase and the consonant length is 1, which indicates that the sonant phase and the entire duration of the abutting pair are almost identical.

Figure 2, II, shows the arresting g combining with the releasing p to form a compound consonant at a syllable rate ca. 3-4 per sec. The only true abutting consonants in Figure 2, II, appear in group 2. The syllable rate for group 3, is ca. 3 per sec. In this case the original abutting consonants have become compound and sonant even at this slow rate. Voice from the sonant arresting consonant invades the surd releasing consonant very early.

Surd-Nasal Groups

As long as the trochee accent persists the relationship between the total abutting consonant duration and the sonant phase of this group follows the same general patterns of those

discussed in the surd-sonant groups with the same accent. Figure 3, III, is a record of map map map map spoken with the following accent: ∪ ∪ ˉ ∪ . Syllables 3 and 4 of groups 1 and 2 may be considered as spoken with a trochee accent. The only true abutting consonants follow the accented syllable. The surd phase occupies a larger portion of the consonant duration than does the nasal phase. The air pressure of the arresting occlusion is not dissipated because the accents protect it. So long as the accent operates, the arresting surd consonant stroke is prominent so that it drives the nasal releasing consonant partly into the next vowel. At a syllable rate higher than 3.5 per sec. the surd p forces the nasal m to occupy a shorter and shorter duration. As the rate increases beyond this point, the consonant length decreases, but the surd phase increases, relative to the total consonant length. The reason that such a modification must occur is due to the action of the velum. As the interval between vowels decreases, the velum opens nearer and nearer to the vowel since the arresting of the accented consonant syllable occupies most of the consonant duration. At a syllable rate higher than 4 per sec. the p moves to the releasing position to form a compound consonant. Then the velum opens during the consonant occlusion to dissipate the air pressure for the p. But even then the consonant is almost completely surd.

Nasal-Surd Groups

The trend of the assimilation process and the degree of assimilation occuring in this group are, in general, identical with those occurring in the sonant-surd groups. Figure 3 shows pam pam pam pam spoken with the following accent: ˘ ˘ ˊ — ˘ . Syllables 3 and 4 of groups 1, 2, and 3 may be considered as being spoken with a trochee accent. Abutting consonants appear between these syllables. The air pressure tracings A and N show the prolongation of the accented syllables. The nasal phase of the abutting consonants m:p of the accented syllable occupies almost the entire abutting consonant duration. At rates higher than 4 per sec. when the m combines with the p, the entire consonant becomes nasal, although the consonant generally shows an aspiratory phase indicating a fortis release for the p. Assimilation is rapid and complete at a syllable rate of 3-4 per sec.

In the sonant-surd groups spoken with a trochee accent, assimilation is rapid and practically complete at a syllable rate of 4 per sec. The process is not so rapid in the surd-sonant groups. Nevertheless, a large degree of assimilation occurs up to a syllable rate of 4 per sec.

4. The Iambic Accent Pattern

Surd-Sonant Groups

When the second syllable of a unit group containing a

sonant-arresting and surd-releasing consonant is accented and the unit group is spoken with increasing rate, the sonant modifies the surd consonant of the abutting pair. Assimilation takes place rather rapidly although the process is not as clear cut and uniform as in some of the other groups. Figure 5, Curve I, shows that even at slow rates the sonant phase occupies a large part of the abutting consonant duration. At increasing rates the length of the sonant phase increases in relation to the abutting consonant duration. At a syllable rate of 5 per sec. the critical ratio between the consonant length and the sonant phase is less than 2. This value suggests that the consonant length and the sonant phase are practically identical.

The abutting consonants t:d of the phrase Will that do? of groups 2 and 3 in Figure 4, VI, are completely sonant. Assimilation is almost complete at a syllable rate of 3-4 per sec. in groups 2 and 3. The accent drives the air pressure of the d to a higher level than is usual for the d. The originally prescribed abutting t:d of the phrase at dawn, groups 1, 3, and 4 in Figure 4, III, have combined to form a sonant compound or single consonant. The average syllable rate for these three groups is between 3-4 per sec. The syllable rate for group 4 is 4 per sec. The originally prescribed abutting t:d appears only in group 2 where the syllable rate for this group is 3.3 per sec. Even in this

case, however, the sonant phase occupies almost the entire duration of the abutting pair.

Sonant-Surd Groups.

The abutting consonants of iambic feet containing sonant-arresting and surd-releasing consonants spoken with increasing rates seems to offer an anomoly insofar as the influence of the accent is concerned. In all the groups thus far discussed the consonants of the accented syllables have assimilated the consonants of the unaccented syllables. In this group the sonant phase of the arresting consonant of the unaccented syllable rather than the surd phase of the releasing consonant of the accented syllable gains in accendency as the syllable rate increases to 4 syllables per sec. The releasing surd, however, remains firm up to a rate of 4 to 5 syllables per sec.

Figure 5, Curve IV, shows the relationship between the abutting consonant duration and the sonant phase at different syllable rates. At an average syllable rate of 2 per sec. the surd phase is 1.6 times the length of the sonant phase. But this relationship changes immediately as the syllable rate increases beyond 2 per sec. At a syllable rate between 2 and 3 per sec. the abutting consonant length decreases while the length of the sonant phase actually increases so that the surd phase is only two-thirds as long as the sonant phase. At a syllable rate between 3 and 5 per sec. the sonant phase does

not decrease perceptibly, while the total consonant decreases rather rapidly beyond 4 syllables per sec. There is an increase of the sonant phase in relation to the total consonant length. At a rate of 5 syllables per sec. the length of the sonant phase is double that of the surd phase. The consonant length and the sonant phase probably meet at a rate between 5 and 6 per sec.

Figure 2, III, is a record of the unit group bagpipe spoken with an iambic accent and with increasing rate. The syllable rate for group 3 is ca. 3 per sec. The originally prescribed abutting g:p have probably combined to form a compound. The consonants of groups 1 and 2 have a prominent surd phase. The consonant of group 3 has a relatively larger sonant phase. The fact that the surd-releasing does not impose its surdness on the sonant-arresting consonant makes the behavior of the abutting consonants of this group appear to be different from that of the other groups. But the difference is only superficial. Although the releasing surd does not change the arresting sonant, the arresting sonant does not impose voice on the arresting consonant up to a rate of 4 syllables per sec. A comparison of Curve I and Curve IV of Figure 5 suggests that the accent is definitely a factor in determining the degree of consonant change. The accent in Curve I preserves the identity of the surd-releasing consonant of the accented syllable which in all other

cases loses its distinguishing surdness. The accent in Curve IV, trochee pattern, seems to impose the voice of the arresting sonant upon the releasing surd. At rates higher than 5 syllables per sec. the sonant phase invades the surd region and soon the sonant phase occupies the entire consonant length, but before this change occurs the accent seems to operate in retaining the surd intact.

The Surd-Nasal Groups

The behavior of abutting consonants of syllables containing surd-arresting and nasal-releasing consonants spoken with an iambic accent follows the same general patterns as that of the surd-sonant groups discussed above. Syllables 2 and 3 of groups 1 and 2 in Figure 3, III, may be considered as spoken with an iambic accent and with increasing rate. The average rate for these two groups is 4.5 per sec. The length of the consonants, and the form of the curves, tracings A and N, show that the originally prescribed abutting pim have disappeared. The consonants have now combined to form the compound pm. For this group the critical rate is 4 syllables per sec. Assimilation is rapid at this rate. As in the surd-sonant iambic groups, the influence of the accent seems to preserve the releasing consonant. The consonants between the unaccented syllables 1 and 2 of each group show no nasal phase, whereas the consonants between 2 and 3 show a short nasal phase.

The Nasal-Surd Groups

The same process is active in this group as in the sonant-surd groups spoken with an iambic accent. Figure 3, IV is a record of the phrase pam pam pam pam repeated at an increasing rate and with an accent on the third syllable. Syllables 2 and 3 of each group may be considered as spoken with an iambic accent. The rate of the accented syllable is between 3 and 4 per sec., while the rate of the unaccented syllable is between 5 and 6 per sec. The releasing consonants of all the syllables are compounds of m and p. The rate is too high to tolerate abutting consonants. Voice from the m occupies about half of the consonant duration between syllables 2 and 3 of each group, while the consonant between syllables 1 and 2 is both sonant and completely nasal. The fact that syllable 3 of each group has a heavy accent accounts for the surd phase of the compound mp.

Assimilation occurs rapidly and is practically complete at a syllable rate between 4 and 5 per sec. in the sonant-surd groups. In the surd-sonant groups the degree of assimilation is small. The surd-releasing consonant, however, is prominent and never loses its surd phase.

5. Abutting Consonants Fusing To Form a Third Phoneme

S:y Groups

In certain special cases the abutting consonants fuse to form a third phoneme. In these cases one or both of the

consonants of the abutting pair are weak, unstable consonants which lose their characteristics when they combine. Assimilation is complete when the consonants fuse as a result of increasing rate. The speech material comprising this group consisted of sense and non-sense syllables with s, t, and d as arresting consonants and y as a releasing consonant. Figure 6, III, IV, V, and Figure 7, II, III, IV, and V show syllables with these consonant combinations spoken with an increasing rate alone and in accented groups. When the syllables yos containing s as an arresting consonant are spoken with increasing rates s combines with the releasing y to form sh at an average rate of 3.5 syllables per sec. (See Figure 6, III, IV, V, and Table 3.). At an average rate of 2.9 per sec. both consonants remain abutting consonants. At an average rate of 3.5 per sec. the two consonants fuse to form sh and the abutting pairs never reappear at a rate of 4 per sec. The form of the curve, tracing A, and the rounded form of the aspiratory phase in tracing AO, were used as criteria of the change. Comparison of the fused form of sy (Figure 6, III), and the prescribed sh shows that the two forms are identical. Figure 6, I, and II, shows that a slight difference exists between releasing s and sh. The graphic difference between s and sh as releasing consonants appears in the tracing AO as a slightly higher rise in pressure for the fricative phase of sh. The originally

prescribed s:y changes to a releasing sh at syllable 4. The tracing AO from this point shows a striking similarity to that of sh in record II. As the syllable rate approaches the threshold of change, the arresting s moves towards the releasing y. At a threshold rate the s moves rapidly away for the back stroke, but since the tip of the tongue is also involved in the articulation of the y both s and y combine to form a third sound sh. The accent within limits discussed for the other groups will permit the consonants to function as abutting consonants. (See: Figure 6, IV and V.) But for these accented groups, as in all other groups, abutting consonants are possible only at a rate up to 3.5 to 4 syllables per sec.

T:y and d:y Groups

When the groups containing abutting consonants consisting of arresting t or d and the releasing y were spoken at a rate of ca. 3.6 to 4 per sec., the arresting consonants fused with the releasing y to form a third consonant ch or j. At a syllable rate higher than 4 per sec. the originally prescribed abutting t:y fused to function as a releasing voiced ch. (See: Figure 7, II, III, IV, V.) The criteria for determining the assimilation in this group were (a) the rate of rise of the air pressure in the mouth, A; (b) the shape of the curve; and (c) the affricative phase indicated in the tracing AO. The assimilated ch or j was identified by comparing it with originally prescribed syllables contain-

ing ch or j as releasing consonants. (See Figure 7, I.) The arresting d and the releasing y of these syllables fused to form j at a threshold rate of 3.5 to 4 syllables per sec.

The reasons for these mutations lie in the relationship of the accessory consonant movements to the fundamental syllable pulses. The arresting t to d requires a beat stroke to the bridge of the hard palate. If in rapid speech the back stroke for the t or d fuses with the y stroke so that the t or d explodes through the y the movements are precisely those for ch or j. The movements of the t or d close the oral canal and the air pressure rises. When the arresting t or d is followed by a releasing y the explosion through the y position occurs as soon as the tongue moves away from the hard palate. In normal speech, excepting when the accent falls on the syllable containing the arresting t or d, these two arresting consonants telescope to form ch or j. It is inevitable that this assimilation should occur. The same conditions: position of consonant, degree of accentuation, and increasing rate apply with equal efficacy to this group and to all the other groups reported in this study. (See Figure 7, I, II, III, IV, V, and Table 4.)

DISCUSSION OF RESULTS

The results of this study clearly show that assimilation is a progressive process in time, and that (a) consonant position, (b) increasing rate, and (c) accent, are, within limits, influential factors in expediting or delaying the series of events (sound changes) which inevitably occur. Ultimately the syllable rate becomes the all important factor, because as the syllable rate approximates maximum repetition time (physiological limits) the accessory consonantal movements have become modified in order to accommodate themselves to the fundamental chain of syllable movements. When the arresting consonant loses its function in its proper syllable, consonants no longer abut. At higher syllable rates even accent pattern breaks down. The spondee foot is probably reduced first to an iambic foot; iambic telescoping (11-p.190), and trochaic reduction (11-p.191) modify the chain of syllables still further to an arhythmical series of one syllable feet. But even before these changes occur, assimilation operates while arresting and releasing consonants abut.

In a series of unaccented syllables spoken at a rate between 2 and 3 per sec. there is a tendency for surd arresting or releasing consonants to retain their identity through the abutting stage. As the syllable rate increases from 3 to 4 per sec., the surd consonants, irrespective of their position (arresting or releasing), lose a very important

characteristic (surdness). Although they become completely sonant, they still can be distinguished from true sonants by their fortis release. The direction and degree of assimilation is rapid and practically complete at a syllable rate of 4 per sec. for all the groups except the trochee surd-sonant and the iambic sonant-surd. In the case of the trochee surd-sonant group assimilation does occur, but not to the same degree of that in the other groups. In the case of the sonant-surd iambic group the accent seems to hold the surd phase firm, protecting it from the sonant phase of the arresting consonants. Assimilation may be possibly a trifle more rapid when the arresting consonant is a sonant or a nasal, but this difference is small.

The results of this study definitely show that Grammont's "law of the strongest" (5-p.185) is inadequate as an explanation of assimilation. In the first place, the sonant-surd speed series invalidates the "law of the strongest" since the weak (arresting) consonants assimilate rapidly and completely the stronger (by position) consonant. Second, the sonant-surd trochee groups also violate this law. The consonants, "stronger" by position, are assimilated by the "weaker" consonants. In the case of the spondee surd-sonant and sonant-surd groups there is practically no assimilation, but accent rather than consonant position determines the degree of assimilation. The only groups to which the

"law of the strongest" might apply are the surd-sonant speed series, and the surd-sonant iambic groups. In the first series the increase in rate is definitely the reason for the mutation, while in the second groups the accent is the operative agent in producing assimilation. Even if these two groups could be made to fit the "law of the strongest", this law still fails to account for the assimilation in the remaining groups. The theory of "the law of the strongest" fails to account for the majority of the cases of assimilation, and, therefore, is of little use as an explanation of sound change. The consonant position does affect the assimilation process, but not because it is stronger.

As the syllable rate increases the chest pressure rises. The arresting consonant length decreases. If it is a surd, the length of the consonant closure is not of sufficient duration to eliminate the differential pressure between the mouth and the chest, and the intrinsic muscles of the larynx do not have sufficient time to readjust the glottis for the surd consonant. Vocalization, therefore, continues throughout the consonant closure.

In the case of the nasal arresting consonant the nasal phase occupies almost the entire length of the abutting consonants at a syllable rate ca. 3.5 to 4 per sec., because the velum requires a longer time to open and close.

The nasal releasing consonant is driven closer to the vowel as the abutting length decreases. Since the velum opens during the consonant occlusion, the air pressure of the arresting surd is dissipated; at the same time the nasal consonant loses its vocalization because again, the interval is too short for the readjustment of the glottis for the voice.

Every movement has its own accent or culmination which is generally prominent but may be subordinate in another movement pattern (rhythm). This culmination involves a stress which depends on a more forceful contraction of the muscle groups employed in the production of the movement. The stressed muscular contraction is by necessity longer in duration; but equally important is the fact that the contraction of the negative muscle group, or the positive relaxation phase, must be correspondingly longer in duration. A more forceful contraction requires a greater muscular exertion of both the positive and negative muscle groups. Consequently, more time is required to utter the accented syllables. Within limits, the movements of the arresting consonants of such syllables are not slurred. The strokes are prominent, therefore complete. For this reason the arresting consonant and generally the releasing consonant, if the foot is a spondee, undergo little assimilation. As the syllable rate is accelerated, the abutting consonant length decreases, but both remain prominent as long as the accent is

intact. The syllable rate at which spondee feet can be spoken is naturally limited. A double accent requires a forceful contraction for both syllables. In the spondee coordination, the movement of the abdominal muscles is probably separate and occurs simultaneously with each chest pulse. Both movements are strong and of sufficient duration to permit the proper functioning of arresting and releasing consonants. At a rate higher than four movements per sec. the abdominal musculature is fixated. The strong syllable pulse carries the accent. But accent is an event in time. If the syllable rate is increased there can not be two strong movements. The spondee foot must undergo modification.

But before this alteration takes place the spondee accent will preserve the identify of both arresting and releasing consonants. The accent buttresses the abutting pair against change. For all these groups the arresting consonant phase is of a slightly longer duration than that of the releasing phase. But both consonants have a value of sufficient duration to permit the consonants to function in their proper syllables.

Both the accent and the consonant position operate in the assimilation which occurs when syllables are repeated with a trochee accent. The accented syllable represents the main stroke of the abdominal movements and the heavy stroke of the chest muscles. This syllable will be longer in dura-

tion. It will occupy a good share of the foot length. Because of the strong beat of the accented syllable the arresting consonant will occupy a good portion of the abutting consonant length. The stroke of the releasing consonant of the unaccented syllable is weak and rapid. If it is a surd, voice invades and occupies its entire length. Assimilation is quickly and rapidly effective. If the releasing consonant is a sonant, surdness from the arresting consonant reduces the sonant phase of the releasing consonant, but never completely obliterates it.

If the accented syllable of the iambic foot has a sonant releasing consonant, a large degree of assimilation occurs. The direction of the assimilation is not as uniform as that of the other groups, but the influence of the sonant releasing consonant of the accented syllable on the arresting surd is clear. If the releasing consonant is surd, the accent preserves the surd phase which ordinarily disappears in the other groups. All these mutations occur within limits. At rates higher than 5 syllables per sec. the surd phase disappears completely.

The question as to why the abutting consonants of the iambic foot often show a complete mutation requires an answer. The movement of the iambic foot probably reaches its culmination towards the middle of the accented syllable. The weak unaccented syllable has a relatively higher rate

than that of the accented syllable. The weak arresting consonant stroke of the unaccented syllable is absorbed by the vigorous releasing consonant stroke which does not lengthen the syllable. At higher rates of 6-8 syllables per sec. the whole syllable fuses with the main stroke of the accented syllable.

The slower movement of the velum and the dorsum of the tongue, which coordinate in the production of the nasal consonants, suggests an answer to the behavior of the assimilations in groups containing nasal consonants. The slower action of the velum may deflect the air pressure so that it escapes through the nose. When the accent falls on the syllables containing nasals as releasing consonants, the movement phase requires additional time. Since the voice starts during the consonant occlusion, it colors the preceding consonant. Since the back stroke of the velum requires a longer time, it influences the following vowel. In the case where the nasal consonant is the arresting consonant of the accented syllable, the slower movement of the velum overlaps the following consonant. On the other hand the movements of the velum may dissipate the air pressure and modify both the other consonants and itself, but all the conditions that operate for the other groups operate for this group with the same regularity.

Increased rate of syllable utterance is the all impor-

tant condition which forces two or more consonants to fuse to form a third. Zipf's (18-p.97) explanation, that the relative frequency of occurrence of the two consonants ultimately reduces their relative complexity so that they fuse to form a third, and less complex phoneme, is inadequate since the results of this experiment show that assimilation must occur under conditions of rate and accent regardless either of complexity or frequency. The answer probably lies in the behavior of the arresting consonant. Many arresting consonants fuse with the following releasing consonants in the every day speech of the average individual but do not give rise to a third consonant. Such cases may arise in special instances when the character of the abutting pair is such that a fusion of the two naturally forms a totally different phoneme. On the other hand, assimilations that result from the union of two or more consonants do not always complicate the perception of the prescribed meanings which the speech material symbolizes. Tradition and social approbation eventually may force the acceptance of these assimilations as legitimate language heritage. But in most of these cases the assimilations occur rather quickly because one or both consonants of the abutting pair is weak (the semi-vowel y in the t:y groups) and unstable.

The question concerning the action and influence of the mind in producing assimilation requires an answer. It

was suggested in the earlier part of this paper that since mental causes can not be proved or disproved, there remains the possibility of adducing adequate evidence which would render recourse to mental causes unnecessary. The results of this investigation, and their explanations in terms of a motor theory in which the accessory consonant movements accommodate themselves to the fundamental syllable movements when rate is increased and different accent patterns are prescribed, are offered as evidence that renders recourse to mental causes unnecessary. Ten of the twelve subjects used in the experiment were naive as to the nature of the experiment. In the final analysis the change could not "be in their minds" because (1) they did not know that changes occurred in their speech as rates and accent patterns were varied; and (2) they did not know what changes to expect. Later when some of the changes were pointed out to them they refused to believe these changes occurred in their speech. A consideration of speech movements in action, and the relation of these movements to the experience patterns which they have come to symbolize, and for which they have become convenient substitutes, makes recourse to mental causes unnecessary.

The explanations of the sound changes as set forth in this paper are purely mechanical. Speech is utterly dependent upon a physiological mechanism for its production. The

physiological mechanism is subject to physiological laws which govern all muscle coordinations. Under the conditions which obtain in the production of speech, therefore, sounds (muscular movements) which are placed in certain relationships of space and time must undergo changes which the producing mechanism imposes as a result of more fundamental laws.

SUMMARY

1. The problem investigated was that of the influence of accent and increased rate of syllable utterance on abutting consonants. It was thought that positive results from such an experiment, which could be explained in motor terms, would render recourse to mental causes unnecessary.

2. The experiment was carried out as follows:

a. The kymographic method was used to study the influence of accent and increased rate on abutting consonants. Twelve adults served as subjects. They repeated short non-sensical and meaningful phrases containing abutting consonants with varying rates of utterances, and with varying accentual patterns.

b. Assimilation was induced in special cases (abutting consonants). Syllables containing approximately 2,500 abutting consonants were obtained and measured to

determine the conditions, the direction, and the degree of assimilation.

3. The results from the twelve subjects showed that:

a. When syllables containing surd arresting and sonant releasing consonants were spoken with increasing rate, assimilation occurred rapidly and to a large degree as the rate increased to 4 syllables per sec. At a syllable rate between 4 and 5 per sec., assimilation was complete.

b. The same process operated in the sonant-surd speed series. Assimilation occurred more rapidly and was complete at a rate of 4 syllables per sec.

c. When syllables containing both surd and sonant arresting consonants, and sonant and surd releasing consonants, were spoken with a spondee accent both consonants remained practically firm against change.

d. When syllables containing surd arresting and sonant releasing consonants were spoken with a trochee accent and increasing speed, the direction of the assimilation process was not so rapid as that for the other groups. The degree of assimilation was not so great as that of the other groups.

e. When the accent was a trochee for the sonant-surd groups, the direction of assimilation was very rapid, and the degree quite large. Complete assimilation occurred between a syllable rate of 4 to 5 syllables per sec.

f. When the accent was iambic for the surd-sonant groups, the direction of the assimilation was rapid but not so uniform as that for the other groups. Complete assimilation occurred between a syllable rate of 5 and 6 per sec.

g. When the accent was iambic for the sonant-surd groups, little assimilation seemed to appear. The accent held the surd releasing consonant intact.

h. When syllables containing s, t, and d as arresting consonants and y as a releasing consonant were spoken at rates between 3.5 to 4 per sec., s, t, and d fused with y to form sh, ch, and j.

i. Accent, consonant position, and increased rate operate either to hasten or to delay assimilation at a rate of 3 to 4 syllables per sec.

4. A consideration of the relation of the accessory consonant movements to the fundamental syllable pulse, and the necessity for these consonant movements to accommodate themselves to the basic syllable movements, as a result of increasing rate, accent, and consonant position, offer an explanation of assimilation in terms of a motor theory which makes recourse to mental causes unnecessary.

REFERENCES

1. Avery; Dorsey; and Sickles: First Principles of Speech Training. New York: D. Appleton and Co. 1938 Pp. 518

2. Boring; Langfeld; Weld; and Collaborators: Psychology, A Factual Textbook. London: John Wiley and Sons, Inc. 1935 Pp. 555

3. Cooper, Lane: Aristotle on the Art of Poetry. New York: Harcourt, Brace, and Co. 1913 Pp. 101

4. Craff, William L. Language and Languages: An Introduction to Linguistics. New York: D. Appleton and Co. 1932 Pp. 487

5. Grammont, Maurice. Traite de Phonetique. Paris Libraire Delgrave. 1933 Pp. 480

6. Mudgins, C. V. A Comparative Study of the Speech Coordinations of Deaf and Normal Subjects: Jour. of Genetic Psychol. 1934 44 Pp. 3-46

7. Mudgins, C. V. and Stetson, R. H. Voicing of Consonants by Depression of Larynx. Arch. neerl. d. phonet. exper., 1935, 11 Pp. 1-28

8. Jesperson, Otto: Language: Its Nature, Development, and Origin. New York: D. Appleton and Co. 1932 Pp. 448

9. Longius on the Sublime: (trans. by A. O. Prichard) Oxford University Press. Corrected Impression 1926 Pp. 128

10. Spengler, Oswald: Decline of the West: New York: Alfred A. Knopf 1932, 2, Pp.507

11. Stetson, R.H. Motor Phonetics: Arch. neerl. d. phonet. exper., 1928, 3, Pp. 1-216

12. Stetson, R. H. Speech Movements in Action: Transactions of the Am. Laryngol. Assoc., 1933, 55, Pp. 1-13.

13. Stetson, R. H. The Relation of the Phoneme and the Syllable: Proceedings of the Second International Congress of Phonetic Sciences. London 1935 Pp. 245-252.

14. Stetson, R. H. Theory of Rhythm and Discrete Succession. The Psychol. Rev. 12, 1905 Pp. 250-270; 293-350

15. Stetson, R.H. and Fuller, F.L. Dipthong Formation, A Preliminary Study. Arch neerl. d. phonet. exper., 1930, 5, Pp. 31-36

16. Stetson, R.H. and Hudgins, C.V. Functions of the Breathing Movements in the Mechanism of Speech. Arch. neerl. d. phonet. exper., 1930, 5 Pp. 1-30.

17. Vendryes, J. Language: A Linguistic Introduction to History (trans. by Paul Rodin), New York: Alfred A. Knopf. 1925 Pp. 378

18. Zipf, George K. The Psycho-Biology of Language: An Introduction to Dynamic Philology. Boston: Houghton Mifflin Co. Boston 1935 Pp. 329

ACKNOWLEDGMENTS

The experimental work for this report was conducted at Clarke School for the Deaf, Northampton, Mass., during the school years of 1936-1937. To Dr. C. V. Hudgins who suggested the problem I express my appreciation for his assistance, for his direction, and for his supervision of the problem. To Dr. H. M. Glick and all those who served as subjects, I am deeply indebted.

TABLE 1

SHOWING THE AVERAGE LENGTH OF ABUTTING CONSONANTS AND THE LENGTH OF THE SONANT PHASE FOR DIFFERENT SYLLABLE RATE FOR THE SOLID-SONANT GROUPS

SYLLABLE RATE PER SECOND

		1	2	3	4	5	6
		SPEED SERIES					
Cons. Length in sec.	No.		14	34	33	27	10
	Mean		.24	.20	.14	.11	.10
Sonant length in sec.	Mean		.18	.16	.13	.11	.10
		SPONDEE					
Cons. Length in sec.	No.		38	57	.42		
	Mean		.30	.26	.21		
Sonant Length in sec.	Mean		.13	.12	.10		
		TROCHEE					
Cons. Length in sec.	No.		11	82	50	10	
	Mean		.34	.26	.22	.15	
Sonant Length in sec.	Mean		.11	.09	.07	.04	
		IAMBIC					
Cons. Length in sec.	No.		5	90	32	15	11
	Mean		.22	.20	.19	.14	.13
Sonant Length	Mean		.13	.16	.12	.13	.11

TABLE 2

SHOWING THE AVERAGE LENGTH OF ABUTTING CONSONANTS AND THE LENGTH OF THE SONANT PHASE FOR DIFFERENT SYLLABLE RATES FOR THE SONANT-SURD GROUP

		SYLLABLE RATE				
		1	2	3	4	5	6
		SPEED SERIES					
Cons. Length in sec.	No.		41	49	48	8	8
	Mean		.21	.16	.13	.11	.08
Sonant Length in sec.	Mean		.16	.15	.13	.11	.08
		SPONDEE					
Cons. length in sec.	No.		25	30	14		
	Mean		.31	.26	.23		
Sonant Length in sec.	Mean		.22	.14	.14		
		TROCHEE					
Cons. Length in sec.	No.		7	77	61	15	
	Mean		.31	.24	.22	.17	
Sonant length in sec.	Mean		.25	.21	.19	.16	
		IAMBIC					
Cons. length in sec.	No.		32	88	42	9	
	Mean		.21	.20	.19	.15	
Sonant length in sec.	Mean		.08	.12	.10	.10	

TABLE 3

SHOWING MEAN, STANDARD DEVIATION, STANDARD ERROR, AND CRITICAL RATIO BEFORE, AT, AND AFTER -t:y-, -d:y-, AND s:y- CHANGE TO ch, j, and sh respectively for increasing speed series.

		-t:y-	-d:y-	-s:y-
Rate of Syllable utterance per sec. before change	No.	51	41	18
	M	2.9	2.8	2.9
	S.D.	.38	.35	.5
	S.E.	.1	.06	.12
	C.R.	4		
Rate of syllable utterance per sec. at change	M	3.6	3.5	3.5
	S.D.	.37	.3	.39
	S.E.	.09	.05	.09
	C.R.	8.7		
Rate of syllable utterance per sec. immediately after change	M.	4.2	4	4
	S.D.	.33	.45	.65
	S.E.	.08	.07	.15
	C.R.	6.2		

TABLE 4

SHOWING MEAN, STANDARD DEVIATION, STANDARD ERROR, CRITICAL RATIO OF SYLLABLE RATE PER SEC. OF UNACCENTED, AVERAGE, ACCENTED SYLLABLE, AND CONSONANT LENGTHS PER SEC. BEFORE, AT, AND AFTER ACCENTED SYLLABLE OF -t:y- -d:y- GROUP

	Rate of unaccented syllable	Rate of average syllable	Rate of accented syllable	Con.L. before accent	Con.L. at accent	Con.L. after accent
No.	179	202	181	138	159	230
Mean	4.8	3.7	2.9	.13	.21	.11
S. D.	1.1	.55	.48	.05	.03	.06
S. E.	.08	.04	.04	.005	.002	.004
C.R.	10	15		14.9	20	

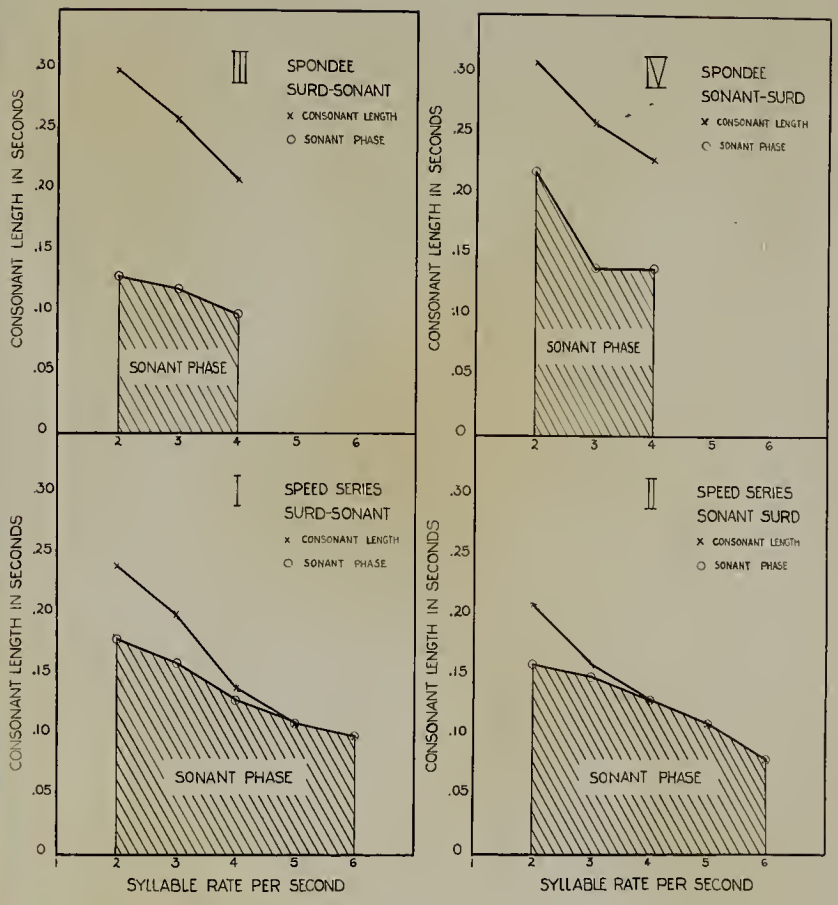

Figure 1

CURVES SHOWING THE RELATIONSHIP BETWEEN THE SYLLABLE RATE, ABUTTING CONSONANT LENGTH, AND SONANT PHASE OF THE SURD-SONANT GROUPS

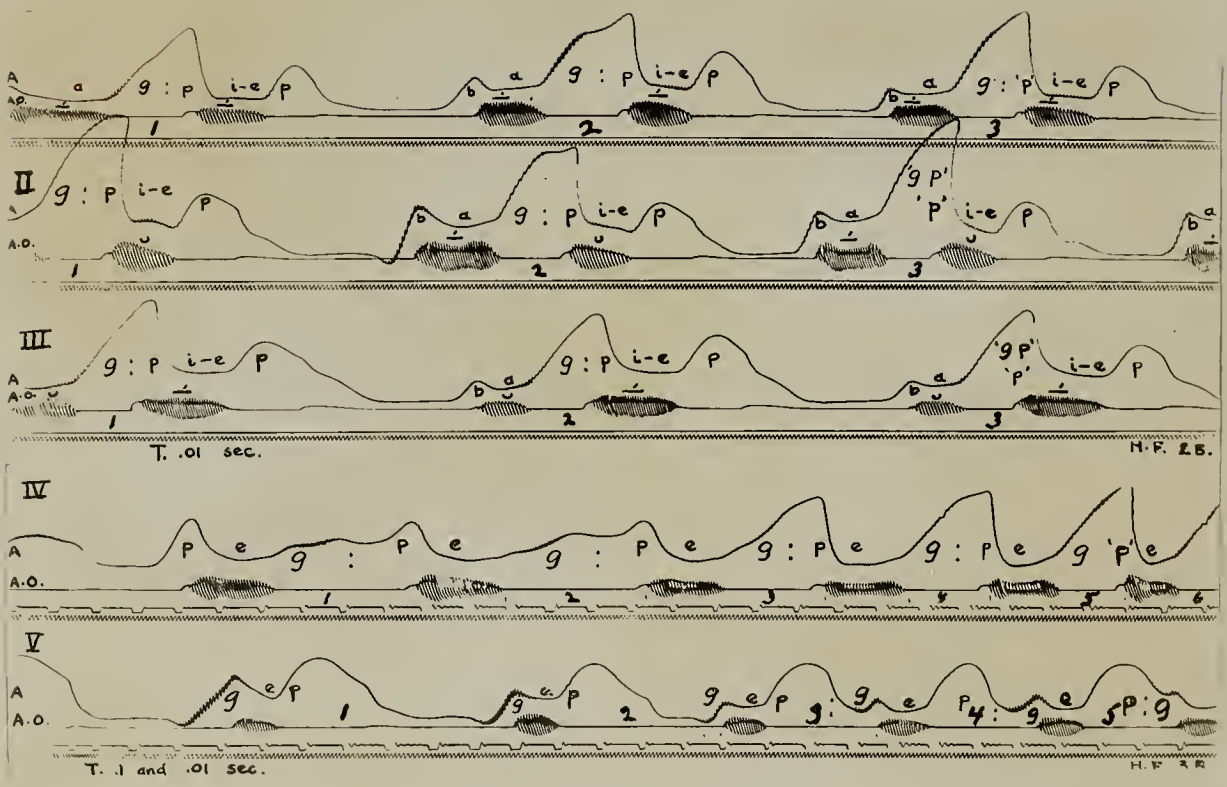

Figure 2

Figure 2

COMPOSITE KYMOGRAM SHOWING SYLLABLES WITH SONANT-SURD ABUTTING CONSONANTS SPOKEN WITH INCREASING RATE AND WITH DIFFERENT ACCENT PATTERNS

I. The words bagpipe spoken with increasing rate and spondee accent pattern.

A-tracing of the air pressure inside the mouth. The abutting consonants of groups 1 and 2 show the sonant-surd phases of the consonants. The air pressure for p is higher than that of g. The abutting consonants of group 3 are completely sonant. The air pressure curve indicates that the prescribed abutting consonants have become a compound or single consonant. The p has a fortis release. The duration of the consonant, .14 seconds, is too short for that of abutting consonants.

AO-tracing of the air pressure just outside the mouth. The sudden rise of pressure before the voice begins for the vowel shows the aspiration phase of the releasing p.

II. The words bagpipe spoken with increasing rate and with trochee accent pattern.

A-tracing of the air pressure inside the mouth. The abutting consonants of group 2 are almost completely sonant. The prescribed abutting consonants are not present in groups 1 and 3. The air pressure curves are those of compound or single consonants. This consonant is completely sonant. The pressure for the 'p' is the usual form for the releasing p, and indicates that it is a fortis release.

AO-tracing of the air pressure from just outside the mouth. The aspiration phase for the releasing phase for the releasing p is clear throughout. Note the greater length of the vowel in the accented syllables.

III. The words bagpipe spoken with increasing rate and with iambic accent.

A-tracing of the air pressure inside the mouth. The

lengths of the consonants in all the groups (.13 sec.) indicate that the originally prescribed abutting consonants have become compound or single consonants. The consonants of group 1 and 2 have a prominent surd phase. In group 3 the consonant has a greater sonant phase. The syllable rate for the 3 groups is 3-4 per sec.

AO-tracing of the air pressure from just outside the mouth. The releasing p has an aspiration phase which decreases with increases rate.

IV. The syllables peg, peg.... spoken with increasing rate.

A-tracing of the air pressure inside the mouth. Voice from the g is entering p in abutting consonants of syllables of syllables 3 and 4. The releasing 'p' of syllable 6 is completely sonant. The air pressure curve is approaching the form of a compound or a single.

AO-tracing of the air pressure just outside the mouth. All releasing p's have an aspiration phase. The aspiratory phase of syllable 6 is partly vocalized.

V. The syllables gep, gep... spoken with increasing rate.

A-tracing of the air pressure inside the mouth. Consonants begin to abut at syllables 3 and 4. The relative duration of the sonant phase increases with increasing rate. The rate of syllable 5, 3 per sec., is not high enough to cause modification of the assigned abutting p:g. At higher rates the two consonants become compound and are vocalized throughout, (see: syllable 6, tracing A, IV above).

A-tracing of the air pressure from just outside the mouth.

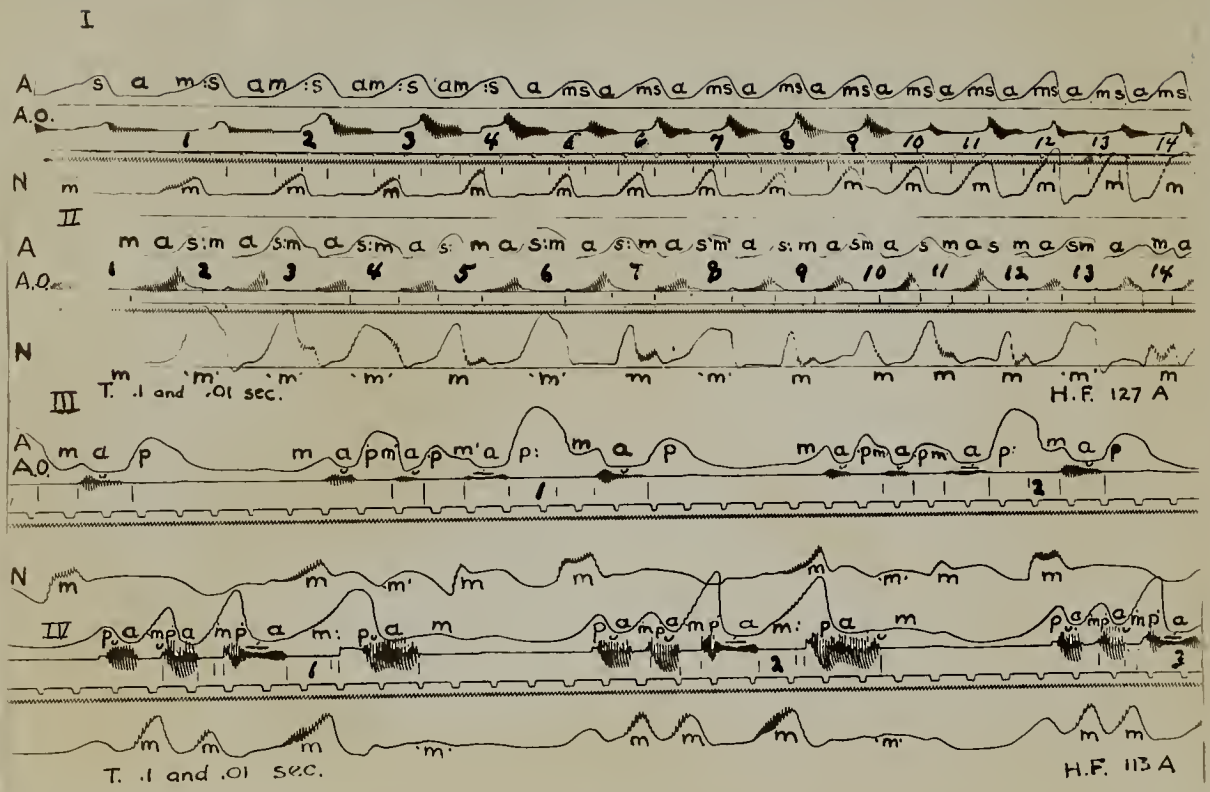

Figure 3

Figure 3

COMPOSITE KYMOGRAM SHOWING NASAL-NON-NASAL, NON-NASAL-NASAL ABUTTING CONSONANTS SPOKEN WITH INCREASING RATE AND WITH DIFFERENT ACCENT PATTERNS

I. The syllables sam, sam..... spoken with increasing rate.

A-tracing of the air pressure inside the mouth. The surd phase of the abutting consonants m:s decreases with increasing rate. At syllable 6 the rate is 4.5 syllables per sec.; sam becomes mza; the abutting m:s become compound mz with vocalization throughout.

AO-tracing of the air pressure from just outside the mouth. At slow rate the fricative phase is surd; after syllables 5-6 it becomes sonant throughout.

N-tracing of the air pressure from the nose. As the rate increases the nasal phase occupies more and more of the consonant duration, until at syllables 11 to 14 it includes the entire consonant length.

II. The syllables mas, mas.... spoken with increasing rate.

A-tracing of the air pressure inside the mouth. The relatively low pressure in the mouth indicates that the pressure for s is being dissipated through the nose (see: N below).

AO-tracing of the air pressure just outside the mouth. Note the form of the vowel just before the arresting s.

N-tracing of the air pressure from the nose. Note the high pressure from the nose and the relatively larger surd phases in m. The velum opens for the m during the occlusion of s, causing a loss of pressure through the nose. The compound sm from syllables 10 on is almost completely surd.

III. Map, map, map, map spoken with increasing rate and the following accent pattern: - - ‿ -

A-tracing of the air pressure inside the mouth. The originally prescribed abutting consonants p:m become compounds or single in the unaccented syllables. The

compound pm of these syllables is practically surd (see: N below). The accented syllable shows the distinct abutting form.

AO-tracing of the air pressure just outside the mouth.

N-tracing of the air pressure from the nose. The normal form of the m appears in the first syllable of each group. The third m of each group is weak and very short. The m following the accented syllable is completely voiced.

IV. Pam, pam, pam, pam spoken with increasing rate and the following accent pattern: _ _ ‿ _

A-tracing from the air pressure inside the mouth. The abutting consonants of the unaccented syllables have become sonant compound or single consonants. The only true abutting pair in the groups are the m:p following the accent.

AO-tracing from the air pressure just outside the mouth. The aspiration phase decreases as the rate increases. The releasing consonants of the unaccented syllables have lost their aspiration phase.

N-tracing of the air pressure from the nose. The m:p of the unaccented syllables are really combination of m and p with the length of a short, single consonant, .06-.10 sec., vocalized throughout. In the accented syllables the m extends almost the entire length of the consonant duration.

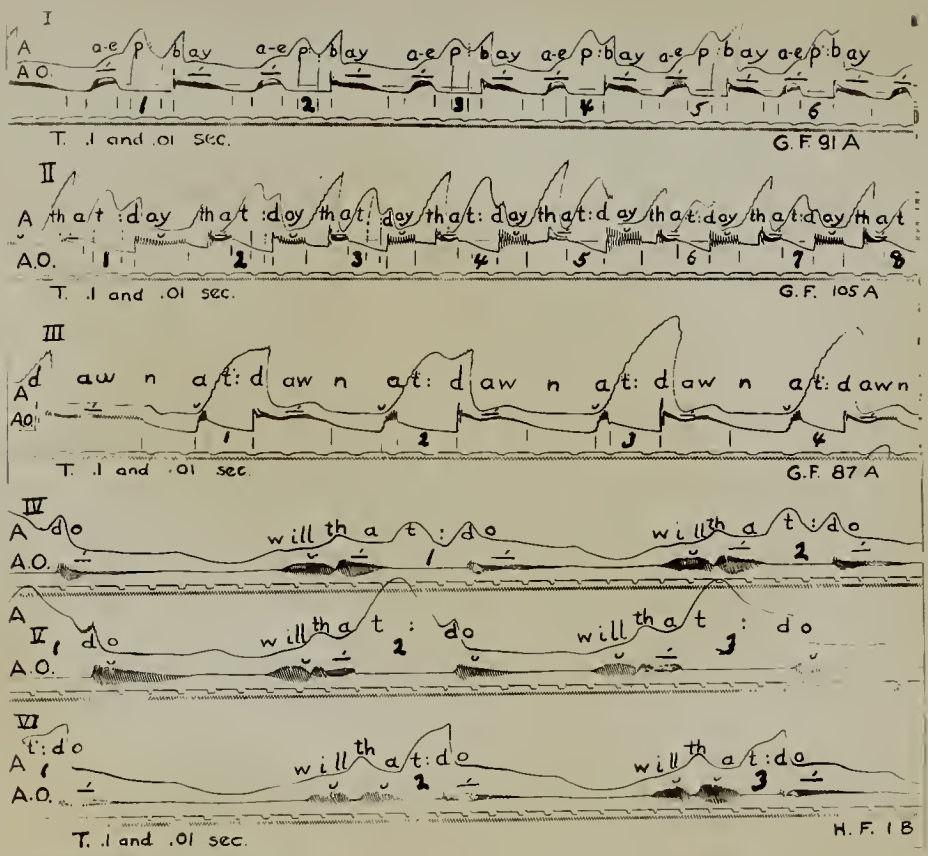
I
A
A.O.
a-e p: bay a-e p: bay a-e p: bay a-e p: bay a-e p: bay a-e p: bay
T. .1 and .01 sec.
G.F. 91 A
II
A
A.O.
that: day that: day that: day that: day that: day that: day that: day that
T. .1 and .01 sec.
G.F. 105 A
III
A
A.O.
d aw n at: d aw n at: d aw n at: d aw n at: d aw n
T. .1 and .01 sec.
G.F. 87 A
IV
A
A.O.
do will that: do will that: do
V
A
A.O.
do will that: do will that: do
VI
A
A.O.
t: do will that: do will that: do
T. .1 and .01 sec.
H.F. 18

Figure 4

Figure 4

COMPOSITE KYMOGRAM SHOWING SYLLABLES WITH SURD-SONANT ABUTTING CONSONANTS SPOKEN WITH INCREASING RATE AND WITH DIFFERENT ACCENT PATTERNS BY TWO DIFFERENT SUBJECTS

I. The unit aps bay spoken with increasing rate and with spondee (ˈ ˈ) accent pattern.

A-tracing of the air pressure inside the mouth. Note the short voice phase carried over from the vowel which appears in the occlusion of the p. The consonants p:b of group 1 do not have the regular abutting form. The surd and sonant phases for p:b are prominent up through groups 5. As the syllable rate increases the surd phase decreases. Beginning with group 6 which is spoken at a rate ca. 5 syllables per second all consonants are complete sonant.

AO-tracing of the air pressure just outside the mouth. The releasing b has no aspiration phase. Voice from the vowel is recorded immediately as the mouth opens.

II. The unit group that day spoken with increasing rate and with trochee (ˈ _) accent pattern.

A-tracing of the air pressure inside the mouth. The d has little voice; in group 2 it is completely surd, while the low amplitude of the air pressure indicates the lenis release. The prescribed abutting consonants have become compound in groups 7 and 8. By this time the accent pattern has probably broken down as a result of increasing rate.

AO-tracing of the air pressure just outside the mouth. The d of the abutting consonant pairs retains the lenis release throughout; there is no aspiration phase, even at high rates, 5-6 syllables per second.

III. The unit group at dawn spoken with increasing rate and with iambic (_ ˈ) accent pattern.

A-tracing of the air pressure inside the mouth. The air pressure curve shows a single, or probably a compound in group 1, rather than an abutting pair. In group 2

abutting consonants reappear. The remainder of the consonants are sonant compounds or singles. The tracing shows that the pressure in the mouth rises higher for the d in the accented syllable dawn than for the d in the unaccented day above, tracing A. II.

AO-tracing of the air pressure just outside the mouth. The d has a small aspiration.

IV. The phrase Will that do? spoken with increasing rate and with a spondee accent pattern for the syllables that do.

A-tracing of the air pressure inside the mouth. The surd t and the sonant d are intact.

AO-tracing of the air pressure just outside the mouth.

V. The phrase Will that do? spoken with increasing rate and with trochee accent pattern for the syllables that do.

A-tracing of the air pressure inside the mouth. In group 1 the surd t abuts with the sonant d. The sonant phase of the abutting consonants is relatively short. The second pair of abutting consonants, group 2, shows a shorter sonant phase. The d of group 3 is completely surd. Although the 'd' has become surd it retains the lenis forms (see AO, below).

AO-tracing of the air pressure just outside the mouth. There is no aspiration for the surd 'd', indicating the lenis form.

VI. The phrase Will that do? spoken with increasing rate. The syllables that do are spoken with iambic accent pattern.

A-tracing of the air pressure inside the mouth. The 't' of the abutting pair in group 1 have a very short surd phase. The air pressure for the d is high throughout. In group 2 and 3 the abutting pairs are completely sonant.

AO-tracing of the air pressure just outside the mouth. There is the usual absence of aspiration for the releasing d.

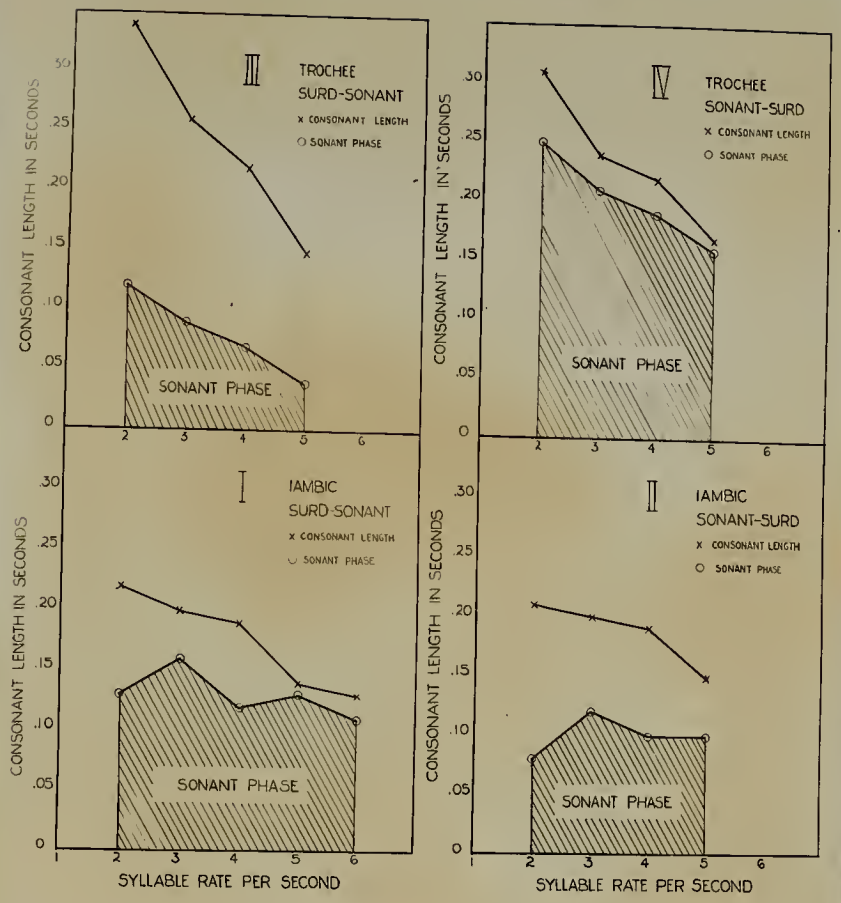

Figure 5

CURVES SHOWING THE RELATIONSHIP BETWEEN THE SYLLABLE RATE, ABUTTING CONSONANT LENGTH, AND SONANT PHASE OF THE SONANT-SURD GROUPS

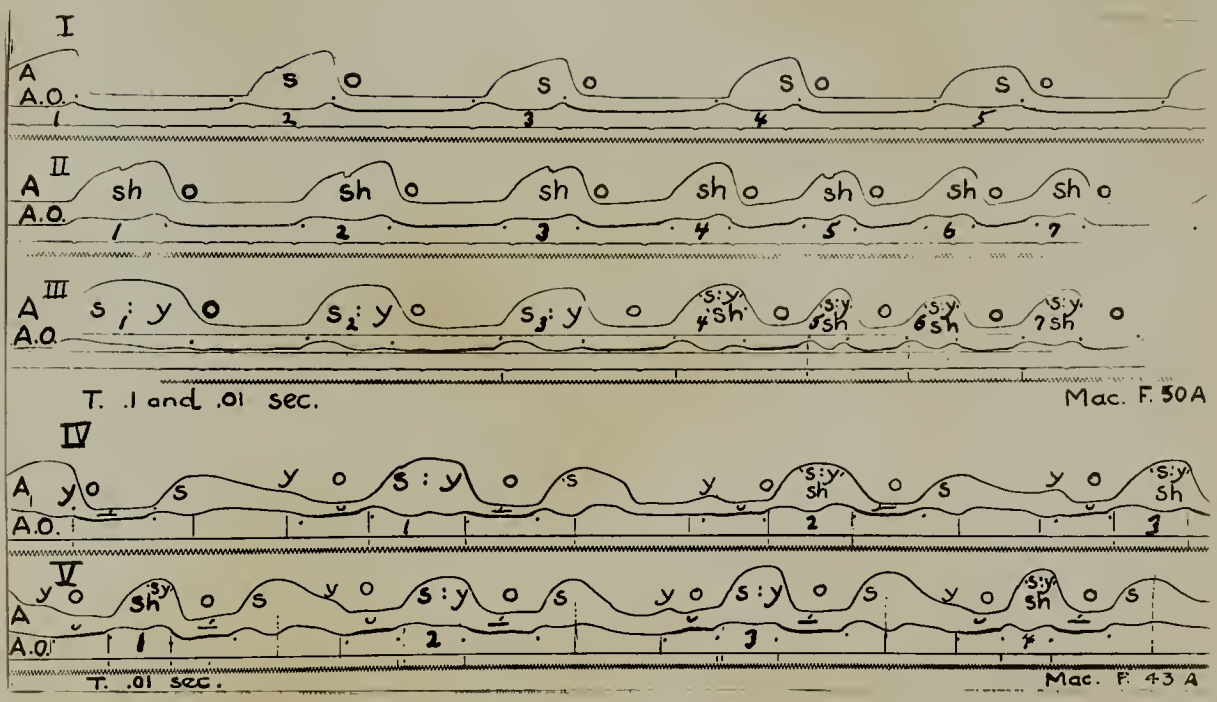
I
A
A.O.
s o
II
sh o
III
s1 : y o
s2 : y o
s3 : y o
s:y sh o
T. .1 and .01 sec.
Mac. F. 50A
IV
y o
s : y o
V
sh
T. .01 sec.
Mac. F. 43 A

Figure 6

Figure 6

COMPOSITE KYMOGRAM SHOWING THE ABUTTING CONSONANTS s:y SPOKEN WITH INCREASING RATE AND WITH DIFFERENT ACCENT PATTERNS

I. The syllables so, so..... spoken slowly.

A-tracing of the air pressure inside the mouth. Note the form of the pressure curve for s. The air pressure rises gradually to a maximum then drops quickly. The dots indicate the length of the vowel.

AO-tracing of the air pressure just outside the mouth. The rounded rise indicates the fricative phase preceding the vowel.

II. The syllables sho, sho.....spoken at an increasing rate.

A-tracing of the air pressure inside the mouth. Notwithstanding the break in the air pressure rise, the rise is gradual to a maximum. Note the roundness of the curves at their maxima.

AO-tracing of the air pressure just outside the mouth. The fricative phase of sh rises higher and is slightly longer than that of s in I above.

III. The syllables yos, yos....spoken at an increasing rate.

A-tracing of the air pressure inside the mouth. Syllables 1, 2, and 3 show distinct abutting consonants. The originally prescribed s:y has become sh at rates of 3-4 syllables per sec., syllables 4, 5, 6. This sh form persists at increasing rates.

AO-tracing of the air pressure just outside the mouth. As the rate increases the tracing shows a fricative phase, almost identical with that of sh in II above.

IV. The unit group yos yos spoken with increasing speed and with iambic accent.

A-tracing of the air pressure inside the mouth. The abutting consonants s:y of group 1 is clear. The consonants of groups 2 and 3 have combined to form

the fricative sh. The consonants between groups 1 and 2 are separate and distinct, but those between groups 2 and 3 show the abutting form.

AO-tracing of the air pressure inside the mouth. Sh forms of groups 2 and 3 are clear.

V. The unit group yos yos spoken with increasing speed and iambic accent. These groups were spoken at a higher rate than those in IV above.

A-tracing of the air pressure inside the mouth. The originally prescribed siy has changed to sh in groups 1 and 4, while those of groups 2 and 3 hold to the original abutting form. The consonant s and y between groups show a slower abutting form.

AO-tracing of the air pressure just outside the mouth. The fricative form of sh is clear in groups 1 and 4.

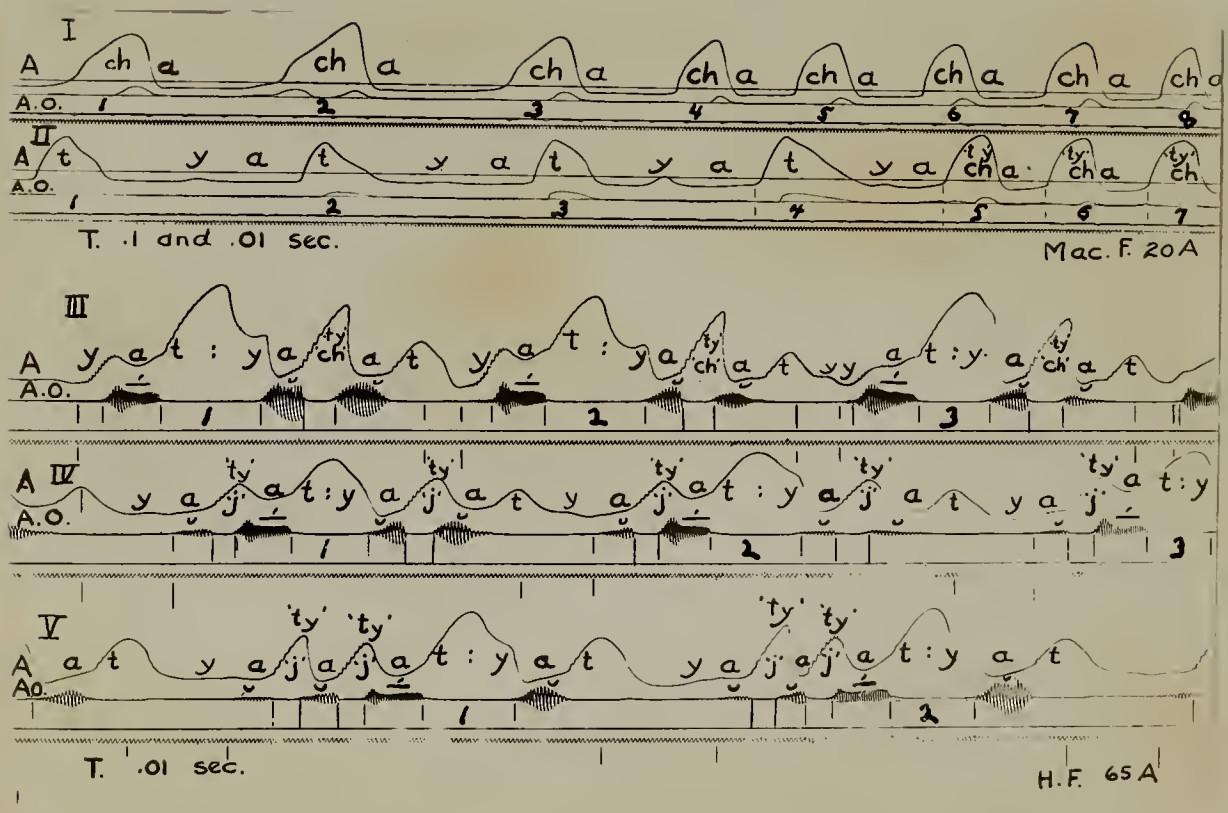

Figure 7

Figure 7

COMPOSITE KYMOGRAM SHOWING THE ABUTTING CONSONANTS t:y SPOKEN WITH INCREASING RATE AND DIFFERENT ACCENT PATTERNS

I. The syllables cha, cha.... spoken at an increasing rate.

A-tracing of the air pressure in the mouth. The air pressure rises gradually to a maximum, shows a regular releasing form.

AO-tracing of the air pressure just outside the mouth. Note the rounded form of the abutting consonant of the affricative phase.

II. The syllables yat, yat.... spoken with increasing rate.

A-tracing of the air pressure inside the mouth. The pressure for the arresting t rises more sharply than for the releasing ch in I above. The originally prescribed t:y become ch from syllables 4-5 on. The rise of pressure is less sharp than that of the arresting t. The curve is the same as that of ch in I above. The rate of syllables 4, 5, and 6 is between 3 and 4 syllables per second.

AO-tracing of the air pressure just outside the mouth. The affricative phase of the ch in AO of I above appears in syllables 4, 5, and 6.

III. The group yat yat yat spoken with increasing rate and the following accent pattern: ‿ - -

A-tracing of the air pressure inside the mouth. The initial continuative y is distinct for each group. The abutting t:y of the first and second syllables remain firm in each group. The two maxima for the t:y are clear. Except for the brief voice in the arresting t from the vowel, both consonants are surd. The pressure of t is much higher than that of the y. The originally prescribed t:y between syllables 2 and 3 of each group has become a releasing consonant; it is either a j or voiced ch. The process is the same for all groups.

AO-tracings of the air pressure just outside the mouth. There is no appearance of the affricative phase in cha in I and II above, indicating that the t:y fused to form ʧ at this rate, ca. 5-6 per sec.

IV. The group yat yat yat yat spoken with increasing rate and the following accent pattern: - ˈ - -

A-tracing of the air pressure inside the mouth. Abutting forms appear between syllables 2 and 3 of each group. The originally prescribed t:y becomes a releasing consonant 'ʲ' in the unaccented syllables 2 and 4 of each group. The accented and the unaccented syllable immediately following the accent show abutting forms with complete surdity for both consonants.

AO-tracings of the air pressure just outside the mouth. The affricative phase is not present.

V. The group yat yat yat yat spoken with increasing rate and the following accent pattern: - - ˈ -

A-tracing of the air pressure inside the mouth. The forms are the same as those in III and IV above. Abutting consonants appear between the accented and the following syllable. Changes are the same as those in IV.

Approved by

C. C. Speet

P. N. Julian

C. V. Hudgins

Graduate Committee

Date June 11, 1937.